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DESIGN, DEVELOPMENT AND PROTOTYPE FABRICATION OF AN AREA HYDROGEN DETECTOR (5 April 1963 Through 4 April 1964)

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THE Bendix CORPORATION

RESEARCH LABORATORIES DIVISION

SOUTHFIELD, MICHIGAN

Report No. 2573

Summary Report:

DESIGN, DEVELOPMENT AND PROTOTYPE FABRICATION OF AN AREA HYDROGEN DETECTOR (5 April 1963 Through 4 April 1964)

September 1964

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George C. Marshall Space Flight Center
Huntsville, Alabama
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SECTION 1

INTRODUCTION

This report describes the design and performance of a compact miniature area hydrogen detector suitable for use in the stringent environments encountered in the unpressurized sections of large rocket booster and sustainer stages. The detector employs the Bendix Palladium-Alloy Film Sensor Element in a specially designed support assembly which provides optimum gas sensing in both sea level pressure environments and those encountered in interplanetary space vehicles. The work was performed under Contract NAS8-5282 sponsored by the NASA George C. Marshall Space Flight Center, Huntsville, Alabama.

Both the mechanical and electronic design aspects of the area hydrogen detector are discussed in Section 2. Performance characteristics of the completed prototype units are discussed in Section 3. Procedures for the installation and adjustment of the area hydrogen which describe the replacement and servicing of the subassemblies. Section 5 presents recommendations of The Bendix Corporation, Research Laboratories Division for additional work to improve the low pressure characteristics of the sensor film elements. The items delivered to NASA under this program are listed in Section 6. Reproducible copies of all pertinent design drawings and parts lists have been forwarded to the George C. Marshall Space Flight Center under separate cover. Copies of these drawings are included in this report as Section 6.

SECTION 2

HYDROGEN DETECTOR DESIGN

2.1 AIR FLOW CONSIDERATIONS

One of the more difficult design problems posed in developing the Area Hydrogen Detector was the extremely wide pressure range over which it must operate. This pressure range extends from one standard atmosphere, or 760 Torr, at the high end, to 10^{-8} Torr at the low end.

At the high pressure end of this range, the transport diffusion time required for hydrogen to travel from a leak to the detector is too slow to provide a useful alarm indication.* Consequently, some method must be provided to create a gross mass movement of gas to the detector. Examples of the mass movements required are those produced by buoyant forces in a gravitational field or the mechanical mixing produced by area blowers.

At the low end of the specified pressure range, molecular motion is essentially line-of-sight, for the size of the system considered, and hence the thermal molecular transport time is very short. Gross mass gas movements based on a gravitational field or mechanical mixing attempts are essentially nonexistent or ineffectual at these particular pressures.

The prototype hydrogen detector overcomes this sampling problem in a unique fashion; two independent gas sampling mechanisms enable the detector to operate in both the high and low pressure range.

The active portion of the detector's sensor element is directly exposed to the area it is to monitor for hydrogen gas. At low pressures, where the gas flow is molecular, the sensor detects the line-of-sight gas molecular flow entering within an oblate conical area whose generating angle is greater than 45 degrees.

*Quarterly Progress Report 5, April 1963 - 30 June 1963; Design, Development and Prototype Fabrication of an Area Hydrogen Dectector, Report No. 2364, The Bendix Corporation Research Laboratories Division

If the environmental pressure is about 100 microns, or higher, the gas flow to the sensor element is increased by a small blower mounted at the base of the sensor assembly. The monitored gas is ejected at right angles to the sensor element plane, thus thoroughly mixing the air near the sensor.

A detailed drawing of the sensor assembly is shown on Engineering Drawing, D2153341, "Area Hydrogen Sensor Assembly." Details of the air flow paths past the sensor element are illustrated in Figure 2-1.

2.2 SENSOR ELEMENT OPERATION

The hydrogen sensor element consists of a thin palladium film deposited on a glass substrate. When exposed to hydrogen gas, the electrical resistance value of the element increases. The magnitude of the change is dependent upon a number of factors; such as, the hydrogen partial pressure, the film temperature, the film resistance, etc. Both the mechanical and electrical design of the detector have been directed toward maintaining all parameters which affect the electrical resistance

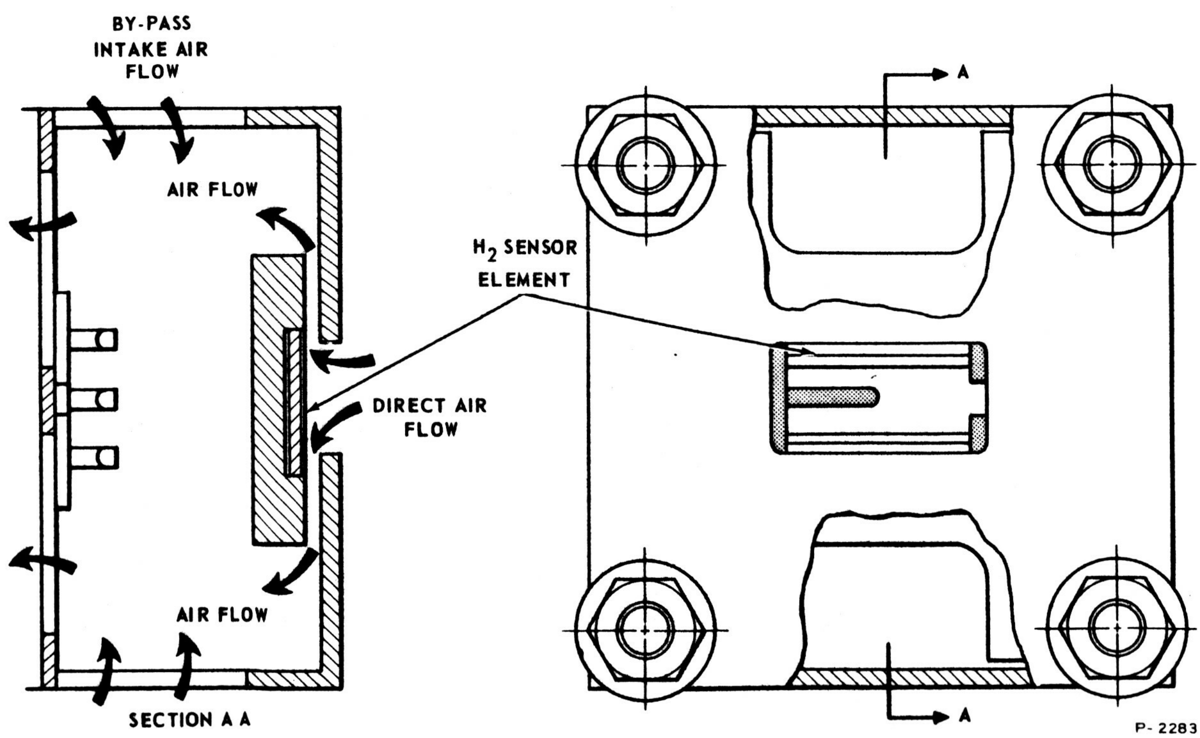

Figure 2-1 - Sensor Assembly - Air Flow Paths

of the sensor element, other than the hydrogen partial pressure, constant over the specified environmental operating conditions. Thus, a change in the sensor element electrical resistance is directly attributable to the hydrogen partial pressure at the surface of the element.

In order to be capable of operating at very low hydrogen pressures, where the changes in electrical resistance due to hydrogen are correspondingly small, it is necessary to control the temperature of the sensing element very accurately. This is accomplished by fabricating the palladium sensor element on an extremely thin sheet of glass, 0.004 inch thick, and then mounting it directly on a thick, temperature controlled, slab of pure silver. Thus, even at very low ambient air temperatures, the palladium film element is maintained within a fraction of a degree of the silver slab temperature, which in turn is held constant to about 0.1°C.

A further increase in operational sensitivity and accuracy is achieved by comparing the resistance of the sensor element to a second palladium film element, a reference element, which is not exposed to the hydrogen containing gas. This technique is much more accurate than measuring the absolute resistance of the palladium sensor element.

Details of the sensor element assembly construction are shown on Engineering Drawing B2153353, and in Figure 2-2. Both palladium film elements are deposited simultaneously on the glass substrate and have, relatively, thick gold contacts deposited on top of the element ends. By depositing both elements simultaneously, their resistances vary by less than one percent and their temperature coefficients vary by less than 0.1 percent. Then one element is covered with a mask to prevent exposure to hydrogen.

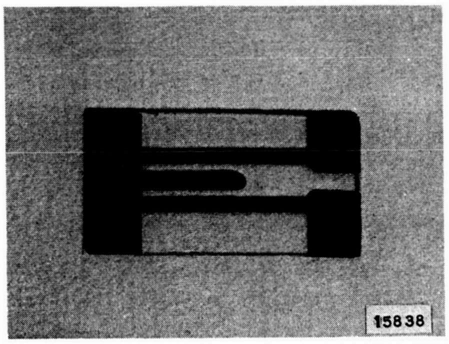

Figure 2-2 - Hydrogen Detector Sensor Element

Sensor element P102-16, delivered with the S/N 103 area hydrogen detector, employs a silicone resin, composed of 40 parts Dow Corning Type R-875 resin, and one part Dow Corning Type 24 catalyst, as the mask material. The other installed sensor elements, P-102-8 and P-102-18, have been masked with a 2.5 mil layer of "Mylar" tape.

2.3 ELECTRICAL DESIGN

A block diagram of the electrical control system for the hydrogen detector is shown in Figure 2-3. There are four functional subsystems: the conductance monitor, the sensor temperature controller, the fan-motor control, and the d-c power supply.

The sensor element and the reference element each form a leg of an a-c operated resistance bridge. Under the condition of zero hydrogen gas pressure, the bridge is balanced by means of the 50 ohm potentiometer shown in the bridge amplifier schematic of Figure 2-4. If the hydrogen partial pressure is raised to some non-zero value, the sensor element resistance increases, thus unbalancing the bridge. The unbalance bridge a-c output voltage is amplified by the three-stage constant gain feedback amplifier. The operational voltage gain of this amplifier is fixed at 50. Since the open circuit gain is in excess of 10,000, the amplifier linearity is very good and the gain relatively independent of the supply voltage level.

The bridge amplifier output signal is a-c coupled to a second high gain feedback amplifier, similar to the bridge amplifier, but with an adjustable voltage gain. The gain adjustment of this amplifier, shown in Figure 2-5, is sufficiently large so that it can accommodate most of the resistance sensor elements produced by the Research Laboratories Division of The Bendix Corporation.

The amplified signal from the second amplifier is transformer-coupled to the synchronous demodulator shown in Figure 2-6, and the reconstituted d-c output voltage of the demodulator is coupled through a low pass filter and overload level clipper to the external telemetry systems.

The gain of the demodulator driver amplifier is adjusted to provide an output of 5 volts for a hydrogen pressure of 3.8 Torr (0.5 percent hydrogen in air at S.T.P.) at the sensor element surface.

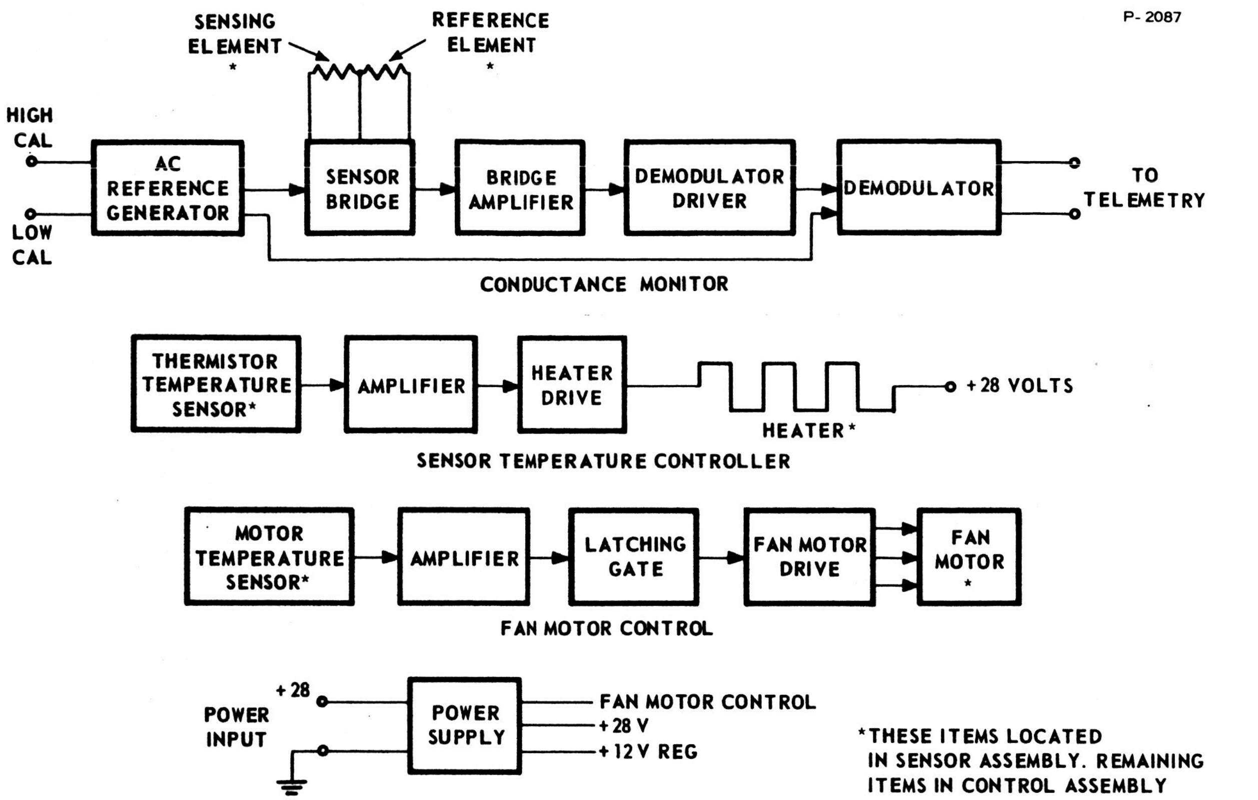

Figure 2-3 - Area Hydrogen Detector, Block Diagram

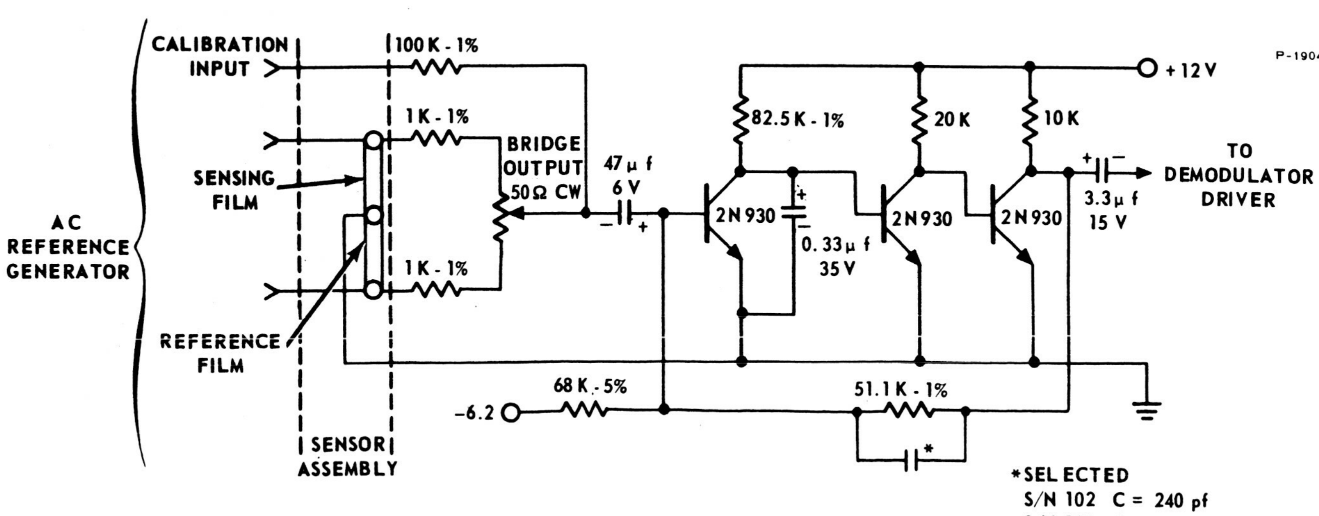

Figure 2-4 - Sensor Bridge and Amplifier, Schematic

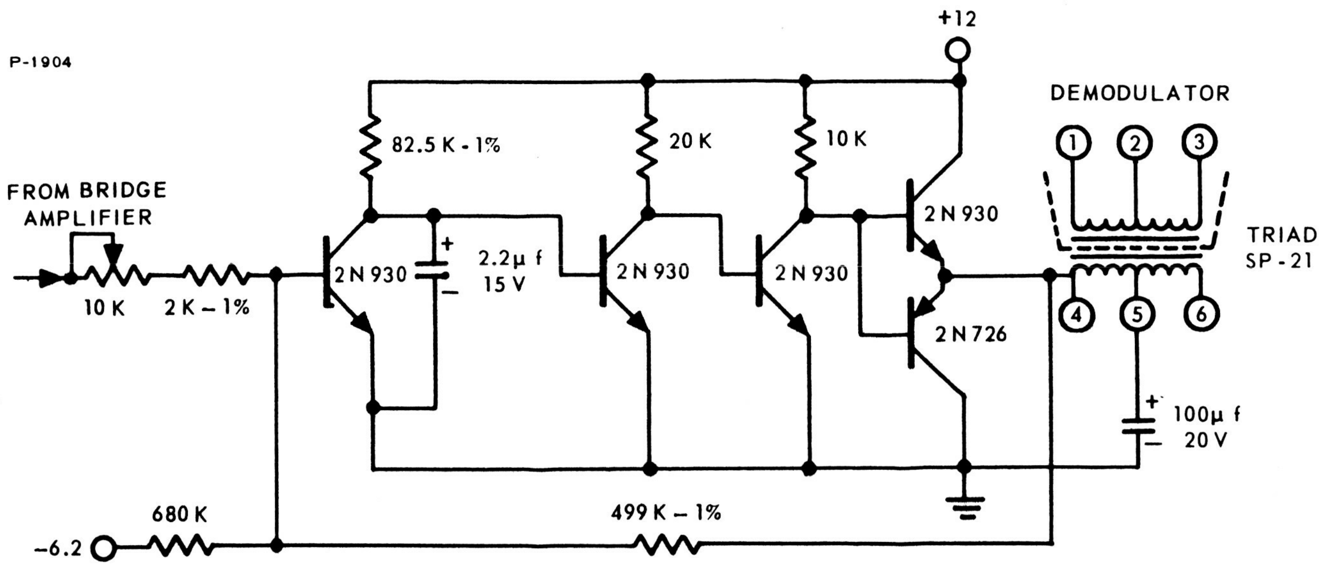

Figure 2-5 - Demodulator Driver, Schematic

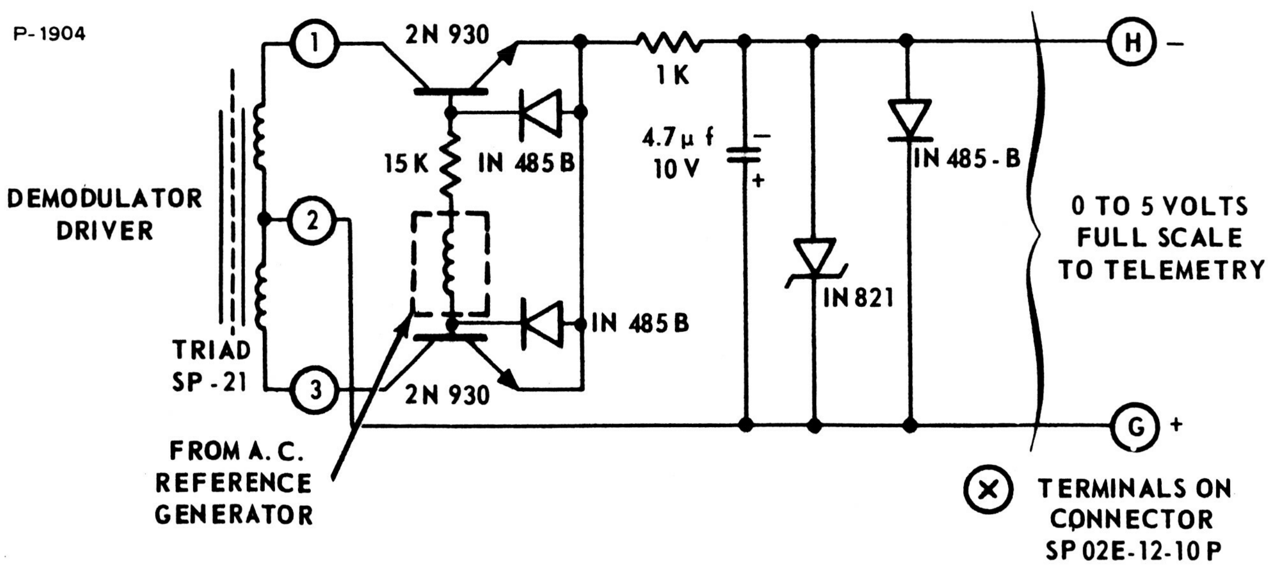

Figure 2-6 - Demodulator, Schematic

The detailed characteristics of the overload level clipper are discussed in detail in subsection 3.3.3. In essence it limits the output voltage to -0.8 to +6.5 volts for any overload in the system. Within the limits of -0.5 to 5.0 volts, the amplifier voltage gain varies by less than one percent. Both the reference signal and the bridge unbalance signal are transformer coupled to the synchronous demodulator, hence complete d-c isolation between the control electronics and the telemetry system is preserved.

Figure 2-7 illustrates the design of the a-c reference generator. It consists of a transformer coupled square wave generator with a number of isolated outputs. One unregulated square-wave output signal is used as the reference voltage in the synchronous demodulator. A second square wave voltage is converted into a negative d-c voltage by a half wave rectifier circuit and then maintained at a -6.2 volt level by means of a zener diode regulator.

A very precise peak-to-peak amplitude controlled square-wave voltage is produced by coupling the unregulated square wave from the transformer secondary through a zener diode regulating circuit employing a double anode reference diode as the clipping element. This controlled square wave voltage is coupled through a step-down transformer to the sensing bridge circuit. This high level controlled square-wave voltage is also used as the reference voltage in the internal calibration system.

The complete calibration circuit, Shown in Figure 2-8, employs a set of 2N930 transistors as shunt attenuators. With +28 volts applied to terminals D and C, both transistors are driven to saturation, effectively shorting the a-c test voltages to ground. If terminal D is grounded, the upper transistor is cut-off and the calibration voltage from the square-wave oscillator is coupled through a 200:1 attenuator to the calibrate test point of the bridge circuit. The actual voltage level is set by adjusting the "Cal. Adj." potentiometer to provide a 90 percent of full scale reading at the telemetry output terminals. If the lower transistor had its input, C, grounded instead of D, the action would be similar, but only a 10 percent of full scale deflection would result because of the higher attenuation ratio.

A constant sensor element temperature, nominally 75°C, is maintained by the sensor temperature controller shown in Figure 2-9. The element temperature is sensed by a thermistor located on the

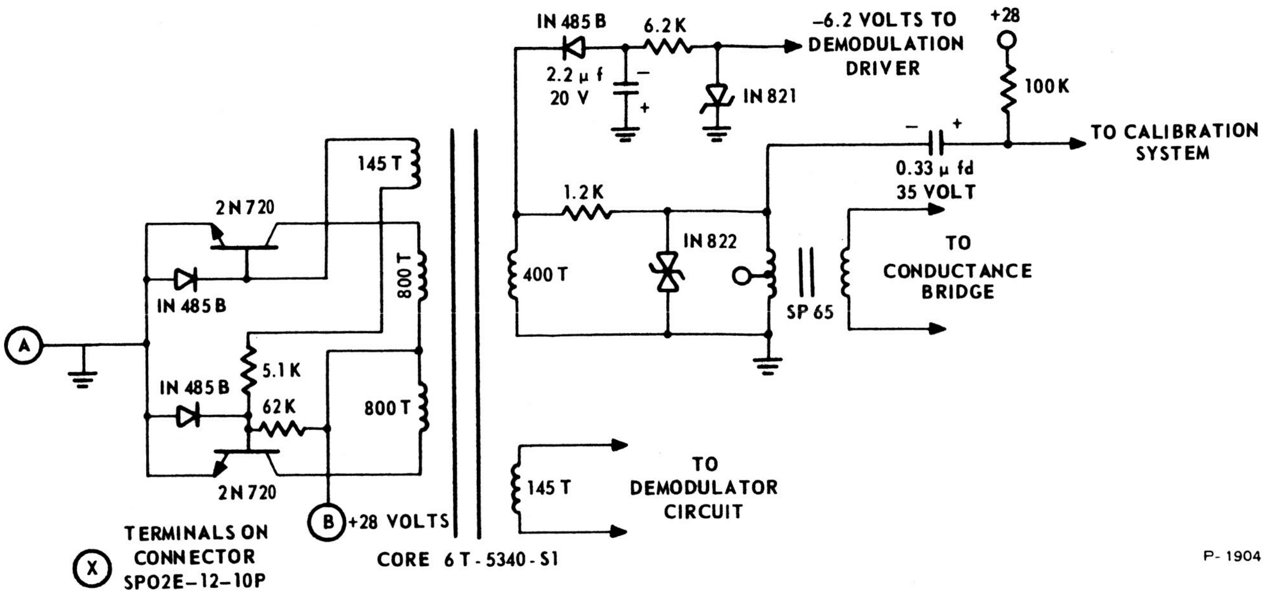

Figure 2-7 - Reference Generator, Schematic

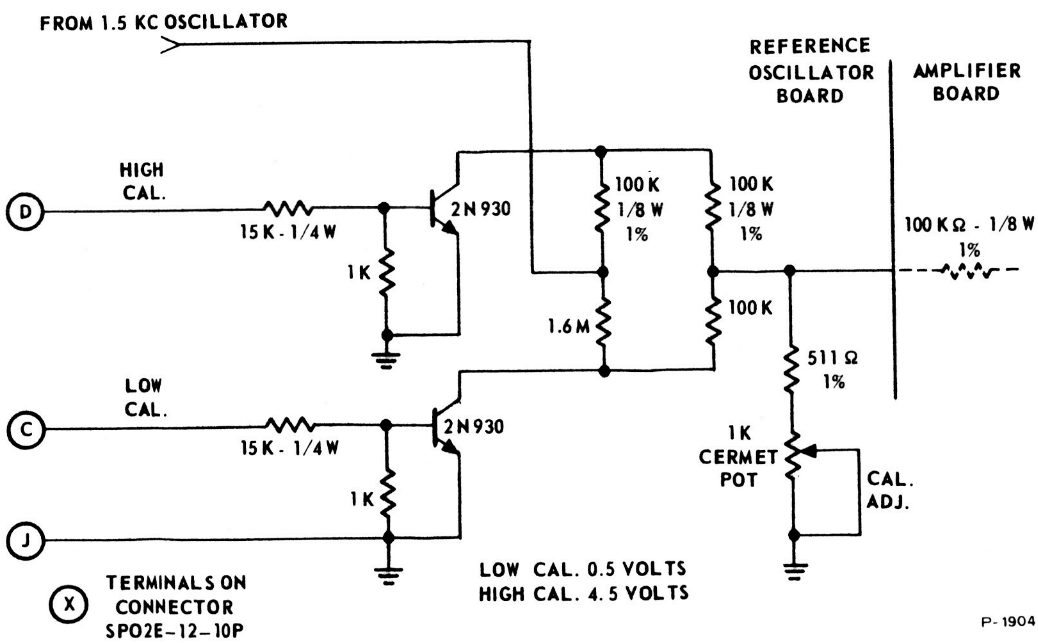

Figure 2-8 - Calibration System, Schematic

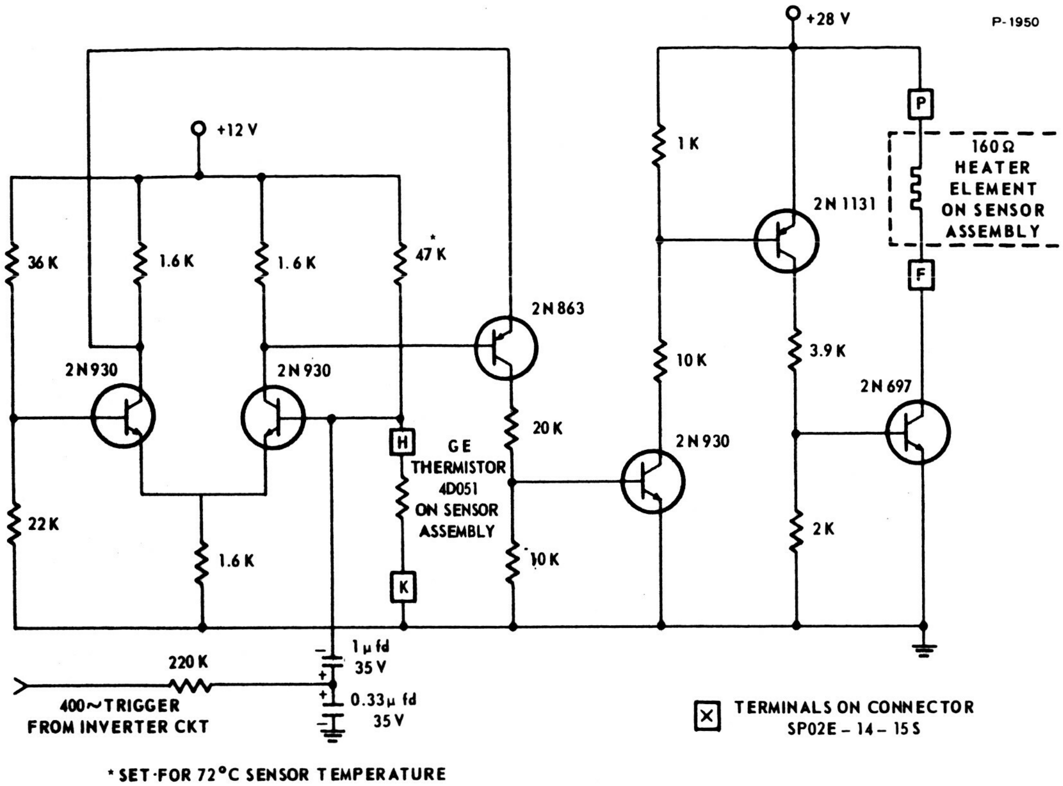

Figure 2-9 - Sensor Temperature Controller, Schematic

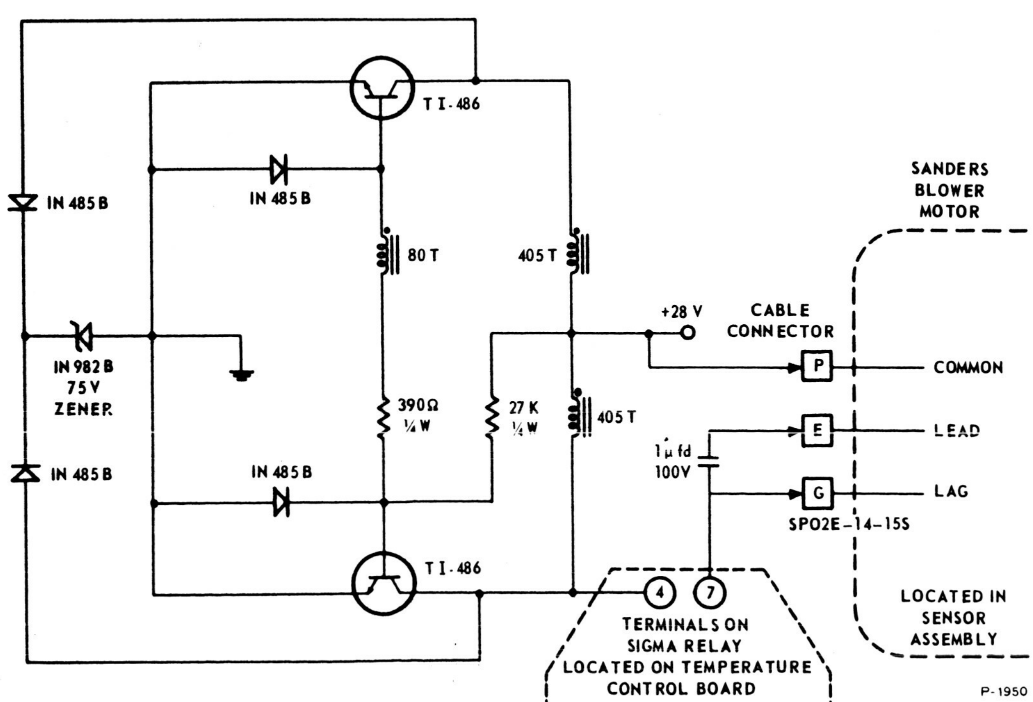

Figure 2-10 - Fan-Motor Drive, Schematic

silver slab heat diffusor (see subsection 2.4), which is connected as one element of a four arm d-c resistance bridge. The bridge unbalance signal is amplified by a transistor differential amplifier and coupled to a very high gain power amplifier. The total gain of the bridge amplifier system is sufficiently large that a temperature change less than 0.001°C causes the heater power level to be changed from full off to full on.

A small a-c coupled triangular voltage waveform is added to the differential amplifier at the thermistor input terminal. This voltage, which has a basic frequency of 400 cps, rapidly switches the power amplifier from off to full on at a 400 cycle rate. The average power requirements of the heater system are not changed by this mode of operation, nor is the sensor temperature at which the system stabilizes. The power dissipation within the amplifier is considerably reduced, however, as compared to the d-c operational mode. This results because the power output transistor is operated alternately in a cut-off condition and a collector saturated condition; both states in which the collector power dissipation is very low. Moreover, by varying the amplitude of the injected triangular voltage, the temperature control system can be stabilized for a wide variety of thermal load time constants.

The blower assembly is designed around a small integrated fan-motor assembly manufactured by Sanders Associates. The motor, which has no brushes or slip rings, requires a two-phase, 400-cycle, 28-volt a-c power supply. The power supply consists of a low power two-silicon transistor self synchronized square wave oscillator, Figure 2-10. A peak clipper consisting of two silicon diodes and a 75-volt zener diode has been added to the collector circuit to prevent high voltage spikes, which could result from motor turn-off transients, from damaging the switch transistors. The clipper circuit also enables the oscillator to operate either with or without a load at input voltages up to about 37 volts. This performance would be difficult to achieve without some form of overvoltage protection.

One motor phase, the lag winding, is directly driven by the square wave voltage waveform that appears between the 28-volt supply and one of the oscillator collector terminals. The lead winding receives its voltage through a one microfarad phase shift capacitor from the lag winding. This method of lead winding excitation results in a higher motor power loss than if pure sine wave voltages had been used. However, it is much simpler and permits the motor to operate within its ratings at temperatures greater than 65°C.

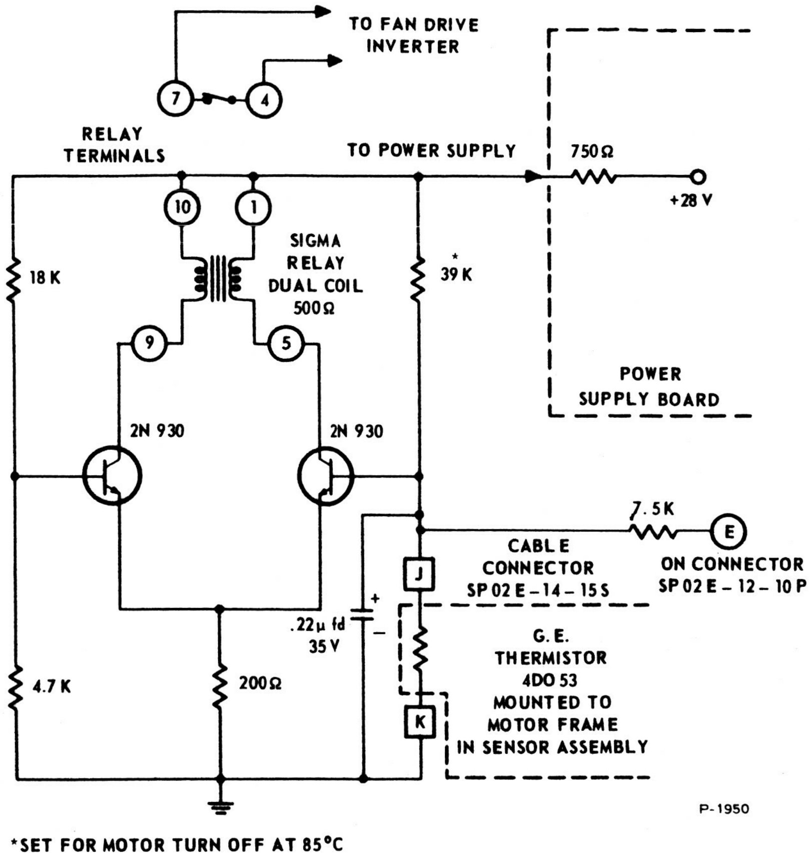

Figure 2-11 - Fan-Motor Control, Schematic

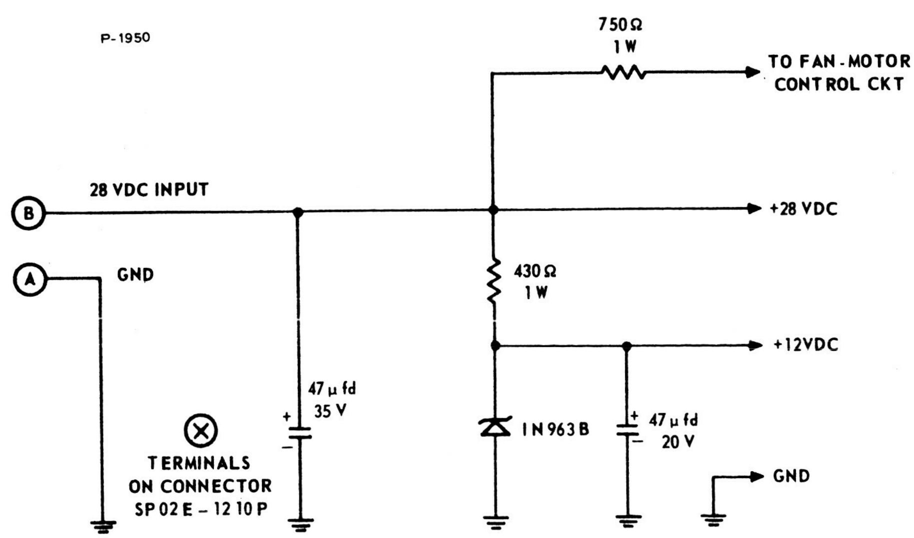

Figure 2-12 - Power Supply, Schematic

As the ambient gas pressure is reduced, the constant speed blower moves a smaller mass of air across the sensor element. In addition, because of the smaller air flow rate through the motor windings, the motor heat loss is reduced and the winding temperatures increase. To prevent the motor from over heating under these conditions, the motor case temperature is sensed by a thermistor located on the end bell and if the sensed temperature exceeds a preset temperature, 85°C in the prototype units, the motor is disconnected from the a-c motor power supply. The motor control circuit, which accomplishes this, is shown in Figure 2-11.

The need for the motor cut-out thermal protection system has not been positively substantiated. Vacuum operational tests showed that if the sensor assembly mounting plate is fastened to a good heat sink, such as a structural frame member of a large rocket, the peak motor temperature would rise only about 54°C above ambient. For an ambient temperature of +60°C, this would result in a maximum case temperature of 114°C which is below the 125°C rating for the motor. It therefore seems that, except for the power dissipation in the blower motor windings, no harm will be done by leaving the drive circuit operational. In the vacuum environment, the blower neither assists nor interferes with the line-of-sight collector efficiency of the hydrogen sensor element.

The power supply, shown schematically in Figure 2-12, is very simple. It employs a single zener diode to regulate the +12-volt output.

2.4 SENSOR ASSEMBLY

The sensor assembly, shown in Figure 2-13 (Breadboard Unit), contains four basic subassemblies: the blower module, the sensor module, the filter module, and the cable subassembly.

The blower module includes the mounting plate, the Sanders Minicube blower, the cable clamp, and motor case thermistor temperature sensor. Its basic function is to circulate the gas through the sensor module at high (greater than 0.1 Torr) ambient gas pressures. It also provides a rugged mounting base for the sensor module.

The sensor module contains the palladium sensor element, masked palladium reference element, heat diffusor, heater, and thermistor temperature sensor. These elements are supported as a 1/32 inch thick subassembly on a glass-epoxy support plate. Surrounding

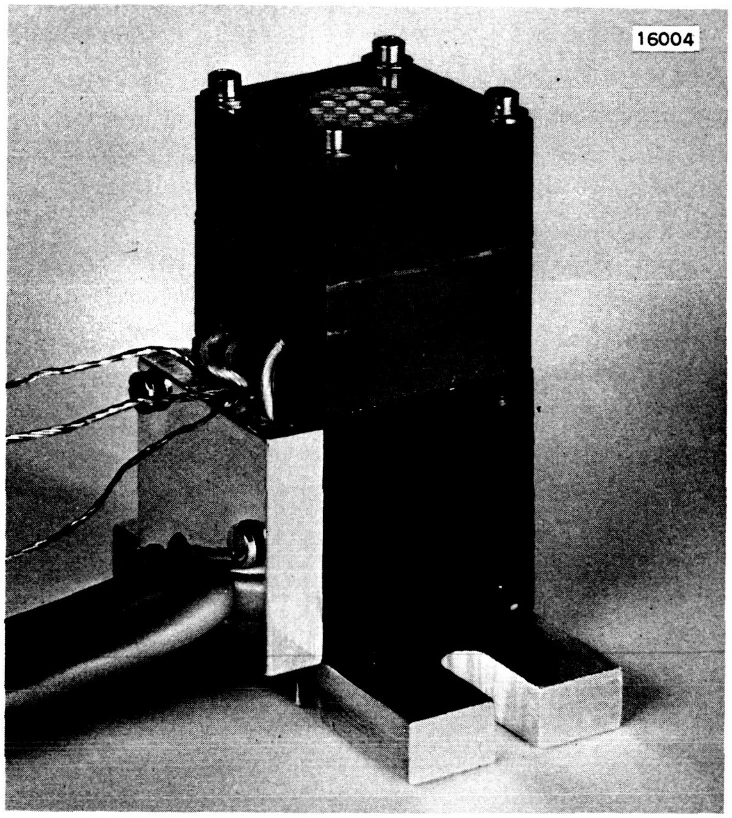

Figure 2-13 - Sensor Assembly

the supported subassembly is an orlon filled diallyl phthatate cover which, with the support plate, forms a contoured air duct around the sensor element. The structural details of these elements are shown on Engineering Drawing D2153341, "Area Hydrogen Sensor Assembly."

At high gas pressures, when the blower is effective, sample air is drawn through the top hole in the cover, across the surface of the sensor and reference elements, and down past the support plate. Additional holes cut into the sides of the cover assist in transporting the sample air to the region of the sensor assembly, however the air flowing through these holes does not pass across the sensor element. The air flowing past the sensor element has a volumetric flow rate of approximately 650 cc/min, whereas the air passing through the side holes has a volumetric flow rate of about 2 liters/min. The flow paths are shown schematically in Figure 2-1.

At low gas pressures, where the gas flow is essentially molecular, the detection of hydrogen depends upon the line-of-sight flow of the hydrogen molecules through the top hole in the cover plate to the sensor element. Under these conditions, the sensitivity of the detector is dependent upon the geometrical location of the hydrogen leak source with respect to the plane of the sensor element. For sources not lying on a line normal to the plane of the sensor element, the sensitivity will vary as the cosine of the source angle measured from the normal. This relationship holds for source angles up to about 45 degrees in the plane bisecting the two palladium elements and up to about 75 degrees in the plane parallel to the sensor elements.

For laboratory use, where many gaseous chemicals are present, some of which might alter the sensitivity of the sensor element, it is recommended that the filter module be used. This module, shown in detail on Engineering Drawing C2153076, "Area Hydrogen Sensor Filter Assembly," fits over the top of the sensor module. It contains approximately one half cubic inch of activated carbon and will filter from the sample air stream oily vapors and other possible contaminants.

The sensor assembly receives all electrical power and control signals from the control assembly and in turn all sensor data (thermal and hydrogen levels) are delivered to the control assembly through the sensor cable subassembly. This cable subassembly consists of three independently shielded, multiple wire cable sets. The identification and function of all wires are stated in Table 2-1.

The cable subassembly has been fabricated to the specified length, of five feet. It is terminated at the control assembly end in a quick disconnect Bendix Pygmy connector type SP02E-14-15P. At the sensor assembly end, each of the cable wires is soldered directly to a solder terminal which in turn is connected to its serviced component. The cable itself is firmly clamped to the side of the blower case by means of a specially fabricated compression clamp. The clamp is made from aluminum in the breadboard hydrogen detector, and from nylon in the two prototype detectors.

2.5 CONTROL ASSEMBLY

The control assembly, shown in Figure 2-14, contains the power supply and all the electronic subassemblies required to control the sensor assembly. These subassemblies are constructed on silicon-glass laminate cards; staked solder terminals are used which help

Table 2-1 - Sensor Cable Subassembly

Cable Set			Wire Color	Destination or Function	Pin Connection on SPO2E-14-15P
Power	Sensor	Thermistor			
X			Bare	Shield Ground	D
X			Green	Fan Motor (Lead)	E
X			White	Fan Motor (Lag)	G
X			Black	Fan Motor and Heater Common	P
X			Red	Heater	F
	X		Bare	Shield Ground	B
	X		Red	Sensor Element	A
	X		White	Reference Element	L
	X		Black	Sensor and Reference Common	M
		X	Bare	Shield Ground	R
		X	Red	Thermistor - Sensor Temperature Control	H
		X	White	Thermistor - Fan-Motor Control	J
		X	Black	Thermistor - Common	K
				Spare	C
				Spare	N

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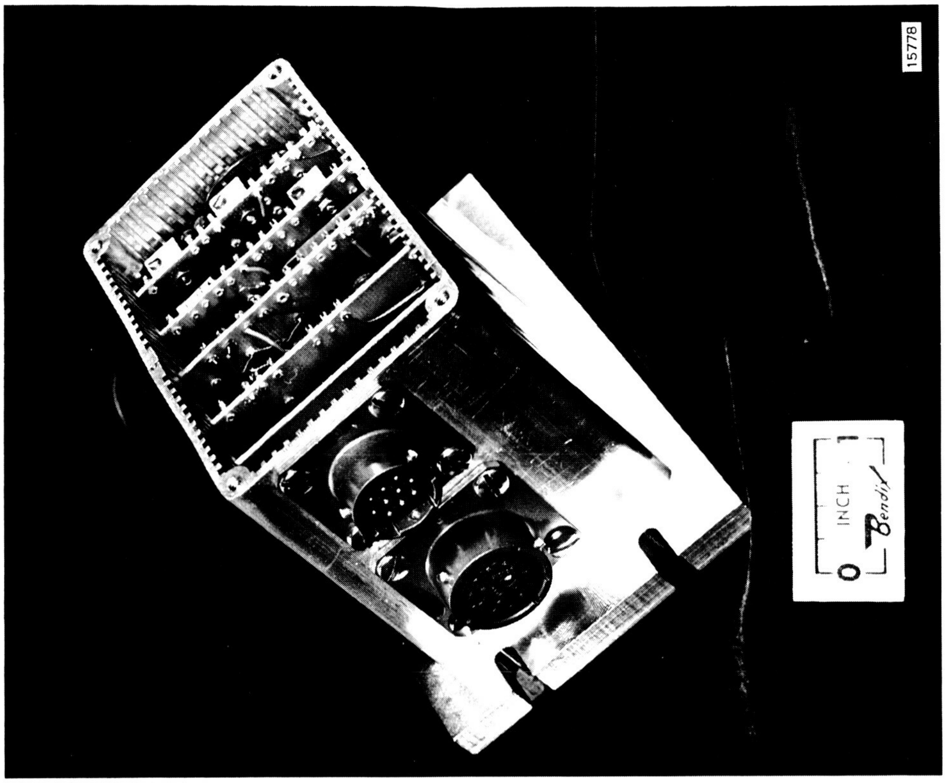
support the components. The component interwiring employes either bare or teflon covered 30 gauge hook-up wire. Printed circuit boards could be used for future models of the hydrogen detector.

The circuit cards, five in number, are spaced in the aluminum case by means of slots in the side walls as shown in Figure 2-14. This mounting technique, while particularly advantageous for prototype units because of the flexibility afforded in card spacing, is also satisfactory for production units. Sponge polyurethane pads (not shown in the photograph) mounted both at the bottom of the case and above the circuit boards at the top of the case act as a pressure clamp on each circuit card. This technique holds all components securely in place, even in relatively high mechanical vibration environments. The two prototype



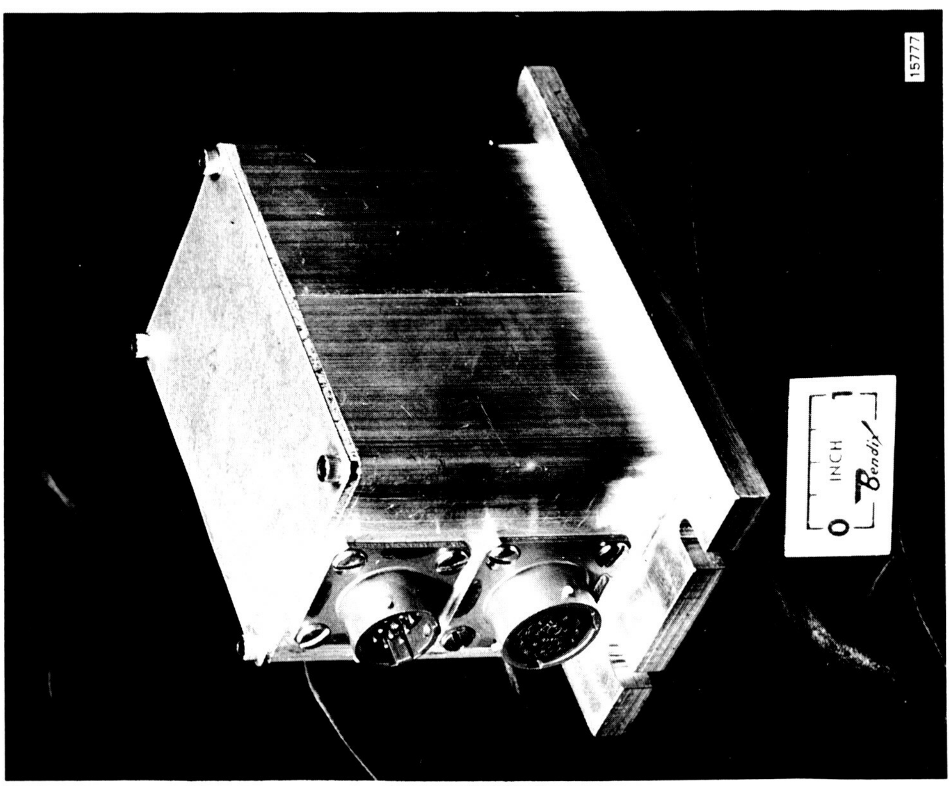


Figure 2-14 - Control Assembly

Table 2-2 - Power Connector Pin Assignments (SPO2E-12-10P)

Pin	Function
A	Power Ground
B	+28 Volts
C	Low Calibrate
D	High Calibrate
E	Motor Cutout Control
F	Spare
G	+ Telemetry Output
H	- Telemetry Output
J	Calibrate Return
K	Shield Ground

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Table 2-3 - Sensor Assembly Pin Assignments (SPO2E-14-15S)

Pin	Function
A	Palladium Sensor
B	Shield Ground, for Wires to Pins A, L, M
C	Spare
D	Shield Ground, for Wires to Pins E, F, G, P
E	Fan Motor (Lead)
F	Heater
G	Fan Motor (Lag)
H	Thermistor (Sensor Temperature Control)
J	Thermistor (Fan-Motor Control)
K	Thermistor Ground
L	Palladium Reference
M	Palladium Common
N	Spare
P	Fan Motor and Heater Common
R	Shield Ground for Wires to Pins, H, J, K

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hydrogen detectors have been further protected against shock and vibration environments by encapsulating the entire interior with silicon rubber foam formed to a density of 10 lb/cu ft.

Pin assignments for both the power input connector and the sensor assembly connector are shown in Table 2-2 and Table 2-3. Different shell sizes and pin numbers have been employed to eliminate any possibility of mismating connectors during installation. Spare pins have been provided on both connectors for possible future requirements.

SECTION 3

PROTOTYPE HYDROGEN DETECTOR CHARACTERISTICS

3.1 GENERAL

One of the principal tasks of the program was the determination of the thin film palladium sensor element properties within the environmental profiles listed in Section 1 of this report. With a knowledge of these properties, it was required to develop and construct a breadboard and two prototype hydrogen detector units. These tasks were accomplished and the characteristics of the sensor film elements and prototype detector units are reported in the following sections.

3.2 SENSOR ELEMENT CHARACTERISTICS

The basic hydrogen sensor element consists of a thin palladium film deposited on a glass substrate. When exposed to hydrogen gas, the electrical resistance value of the element changes. The magnitude of the change is dependent upon a number of factors such as the hydrogen partial pressure, the film temperature, method of preparation, etc.

The characteristics of several specific palladium sensor elements have been reported in the monthly and quarterly reports. This data has been assembled and the general characteristics that influence the operation are discussed in the following subsections.

3.2.1 Steady State Response To Hydrogen

The electrical conductance of the Bendix palladium film sensor elements has been shown to be a function of both the hydrogen partial pressure and the element temperature. The interrelationship between these two parameters is described by the equation

$$G = G_o \left[1 - k, \epsilon^{-\frac{T}{T_o}} P_h^{\alpha} \right]. \qquad (3.1)$$

The validity of this equation has been verified over the temperature range of 50°C to 140°C and over the hydrogen pressure range of 75 Torr to less than 10^{-3} Torr. The terms of the equation

are defined as follows:

G = the electrical conductance of the sensor element in a hydrogen environment at temperatures T expressed in mhos.

G_o = the electrical conductance of the sensor element in a hydrogen-free environment at temperature T expressed in mhos.

T = the sensor element temperature in °C.

P_h = the hydrogen partial pressure in Torr.

α = the dimensionless exponential sensitivity and is approximately 0.5 to 0.6

T_o = exponential temperature constant and is approximately 100°C.

k_1 = a proportionality constant which is approximately 0.01 for the above unit designations.

The electrical circuitry of the hydrogen detector compares the electrical conductance of a sensing element which is exposed to the sample gas with the electrical conductance of a similar element which is masked to prevent exposure to the sample gas. The output voltage of the comparison circuitry is related to these electrical conductances by the expression

$$E_o = k_2 \frac{G_o - G}{G_o + G} \quad . \tag{3.2}$$

Since the hydrogen pressure regime of 0.5 percent of a standard atmoshpere and below is the region of primary interest and since the total conductance change will be less than one percent, Equation (3.2) can be approximated by

$$E_o = \frac{k_2}{2} \cdot \frac{\Delta G}{G_o} \quad , \tag{3.3}$$

where ΔG is the sensor element electrical conductance change due to the presence of hydrogen. Plots of two curves, which show the normalized conductance change versus the hydrogen pressure for sensor

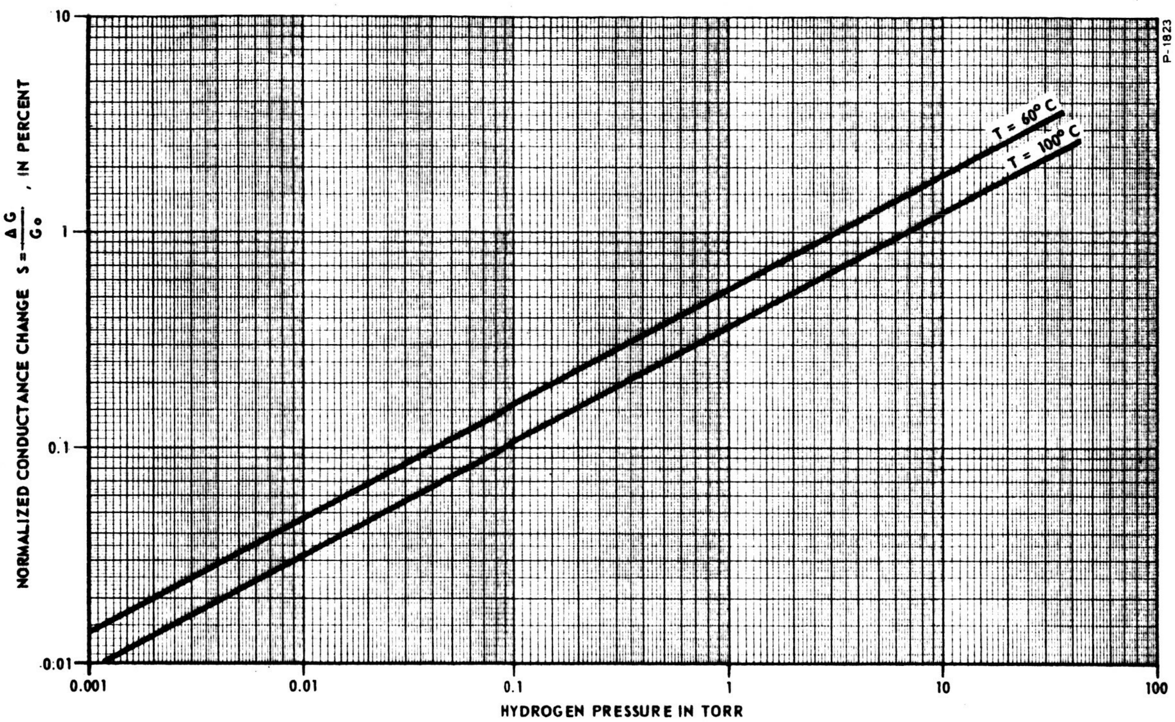

Figure 3-1 - Sensor Element Conductance Change as a Funciton of Hydrogen Pressure

element temperatures of 60°C and 100°C, are presented in Figure 3-1.

In general, the deviation of specific film sensor element responses from these curves is very small; the differences in deviation are due, almost totally, to small differences in the porportionality constant. An element set with a different slope was occasionally produced; however, such occasions were rare.

3.2.2 Sensor Element Response Time

It has been observed that the sensor conductance response to a step change in hydrogen pressure is essentially an exponential rise to a new steady state value; it is described by

$$G_2 = G + \Delta G \left(1 - \epsilon^{-\frac{t}{\tau}}\right) . \qquad (3.4)$$

The magnitude of the step change, ΔG, is in accordance with Equation (3.1). The time constant for the change, τ, is dependent upon several factors; such as, hydrogen pressure, oxygen pressure, element temperature, film thickness, surface purity, etc. An approximate relationship between the time constant for a step increase in the hydrogen pressure and the sensor temperature is defined by the following equation:

$$\tau = P_h^{-B} \epsilon^{\left(\frac{a}{T} - C\right)} \tag{3.5}$$

where

P_h = the applied hydrogen pressure in Torr

T = the film temperature in °C

a = the temperature power coefficient in °C

B = the pressure power coefficient

and

C = a logarithmic proportionality coefficient.

For most sensor elements, B is approximately 0.5, although the measured deviations have been as high as ± 30 percent. The temperature power coefficient, a, is generally about 5000°C and corresponds to a lineal temperature coefficient of just larger than 4 percent per degree Centigrade at room temperature. The logarithmic proportionality coefficient, C, is approximately 13, but has been observed to vary considerably among different sensor elements and even for the same element at different times.

Figure 3-2 illustrates the sensor element response time constant as a function of hydrogen pressure for three different operating temperatures. The curves represent the performance that is obtained from the recent production type of palladium sensor element. In addition, there is evidence that the element response times can be considerably improved by properly choosing the deposition parameters. This factor is discussed more fully in subsection 5.2.2.3.

Operating the elements at higher temperatures tends to decrease the detector response, time constant, but with the presently available sensor elements, an unacceptable conductance drift rate also

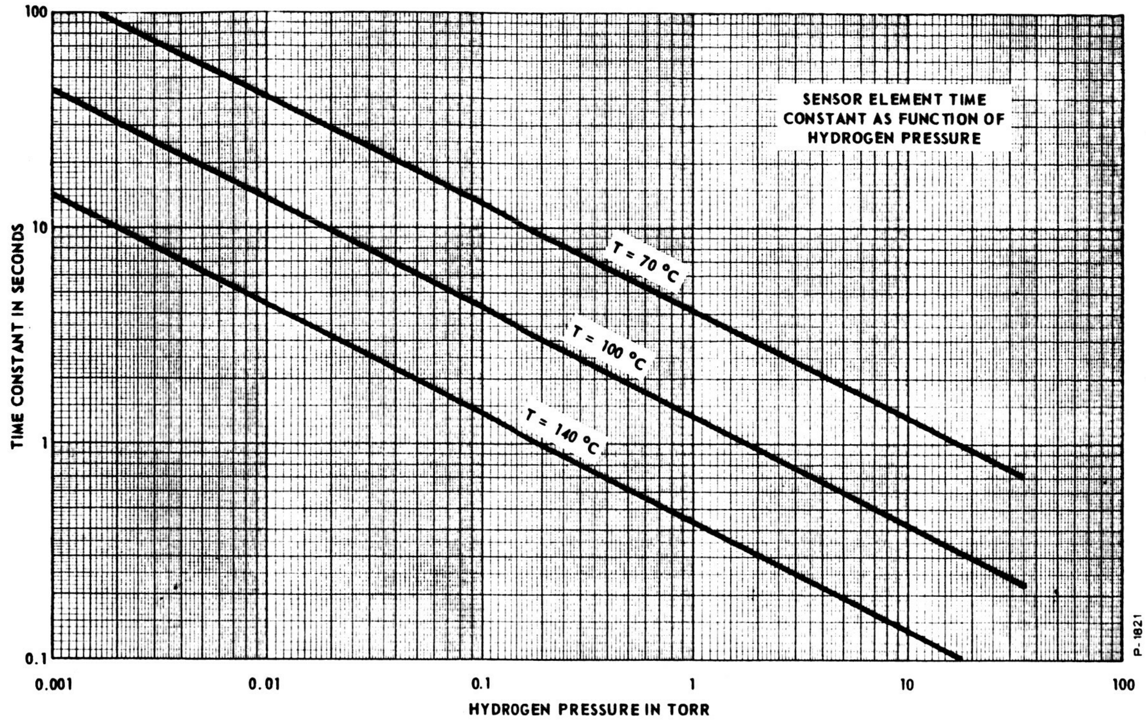

Figure 3-2 - Sensor Element Time-Constant as a Function of Hydrogen Pressure

resulted. However, suitable overlays have markedly improved the high temperature conductance stability. Such overlays coupled with improved deposition techniques should decrease the response time and increase sensor sensitivity. This is discussed in greater detail in Section 5.

3.2.3 Selectivity to Hydrogen

The hydrogen concentration level, at which the palladium sensor element first exhibits measurable changes in resistance, is dependent upon several parameters associated with the Pd-H_2 reaction mechanism. In this reaction, hydrogen molecules are catalytically dissociated at active sites on the palladium metal surface. The resulting hydrogen atoms then migrate over the surface, and ultimately penetrate the palladium lattice, producing lattice perturbations which increase the electrical resistivity in direct proportion to the insitu hydrogen concentration. The net amount of hydrogen absorbed depends upon the ambient molecular hydrogen pressure, the number and reactivity of the active sites, the rate of hydrogen atom recombination and reaction with other gases at the surface, and the rate of hydrogen diffusion through the lattice.

Gases other than hydrogen are capable of being adsorbed on the palladium film surface, where they in turn can affect the number and reactivity of the active sites. In addition, the surface adsorbed gases can also react with the dissociated (and thus active) hydrogen atoms. Such reactions affect both the rate of hydrogen adsorption into the palladium lattice and the net amount absorbed at a given hydrogen pressure; the response and sensitivity, respectively.

All of the commonly encountered gases such as nitrogen, carbon dioxide, water vapor, helium, and argon seem to have little affect on the palladium-hydrogen "reaction." Oxygen, however, interferes. The dissociated oxygen atoms which are adsorbed on the palladium surface readily react with the hydrogen to form water which in turn is easily desorbed from the surface.

The conversion reaction between hydrogen and oxygen at the palladium surface has two distinct effects on the hydrogen detector performance. First, the hydrogen entering the conversion reaction is not available to enter the metal lattice structure, hence the apparent sensitivity of the film element to hydrogen appears to be lower than if oxygen was not present. Second, an apparent marked increase in the detectable or threshold level of hydrogen partial pressure occurs. This results because of the extremely high conversion activity coefficient compared to the solution coefficients.

It appears that the limiting condition for the conversion reaction is the oxygen dissociation rate at the palladium surface. This rate is in turn dependent upon the ambient molecular oxygen pressure and the density and reactivity of the oxygen sensitive active sites. These factors are subject to a considerable degree of modification by various element fabrication techniques; several of these are discussed in Section 5.

Typical sensor elements, such as the P-102 set, have hydrogen threshold levels that generally range from 0.05 to 0.5 percent of the ambient oxygen pressure. The threshold is not noticeably affected by either the sensor operating temperature or the total pressure of the sample gas. It can be affected, however, by surface contaminants such as a liquid oil film. Such a film can alter either the relative reactivity or the density of the hydrogen and oxygen sensitive active sites. It is anticipated that future work, directed toward the reduction of the oxygen active site density, will result in sensor elements whose threshold levels are less than 0.01 percent of the oxygen partial pressure.

3.3 DETECTOR CHARACTERISTICS

The basic hydrogen detector characteristics are primarily determined by those palladium film sensor element characteristics discussed in the previous subsection. In general, such factors as system sensitivity, thermal stability, gain stability, balance stability, control temperature accommodation range, sensor element resistance accommodation range, and electrical response time are all considerably better than that required for proper operation of the currently produced sensor elements. The other characteristics of the system such as detector incremental resistance linearity, output signal characteristics, power, and weight, which are not notably influenced by sensor element characteristics, are discussed in the following subsections.

3.3.1 Conductance Monitor

The conductance monitor portion of the area hydrogen detector is, in essence, an extremely stable and sensitive differential resistance measuring system. It provids a high level output signal, 0 to 5 volts, which corresponds to a maximum film element resistance change of less than 1.0 percent. Moreover, the measurement is required to be invarient over an extremely wide range of ambient temperatures, for a sensor element which has a temperature coefficient of electrical resistance of approximately 0.29 percent per degree Centigrade.

The ambient temperature range variations effect is minimized by comparing the resistance of the sensor film with that of a chemically passive but otherwise similar film and by operating both elements at an accurately controlled temperature. The stability of the measuring system, under normal laboratory conditions, is very good as indicated by the fact that its change in resistance per hour is considerably less than 0.0001 percent.

Because of the large amount of feedback employed in the high gain amplifiers, the effects of transistor parameter changes, supply voltage noise, ripple, and power level changes are greatly minimized. As an example, varying the supply voltage from 21 to 35 volts is equivalent to a change in resistance of only 0.001 percent per volt.

The linearity of the over-all conductance monitor circuitry is limited primarily by the telemetry overload clipper circuit. A typical resistance calibration curve, obtained from the prototype system, is shown in Figure 3-3.

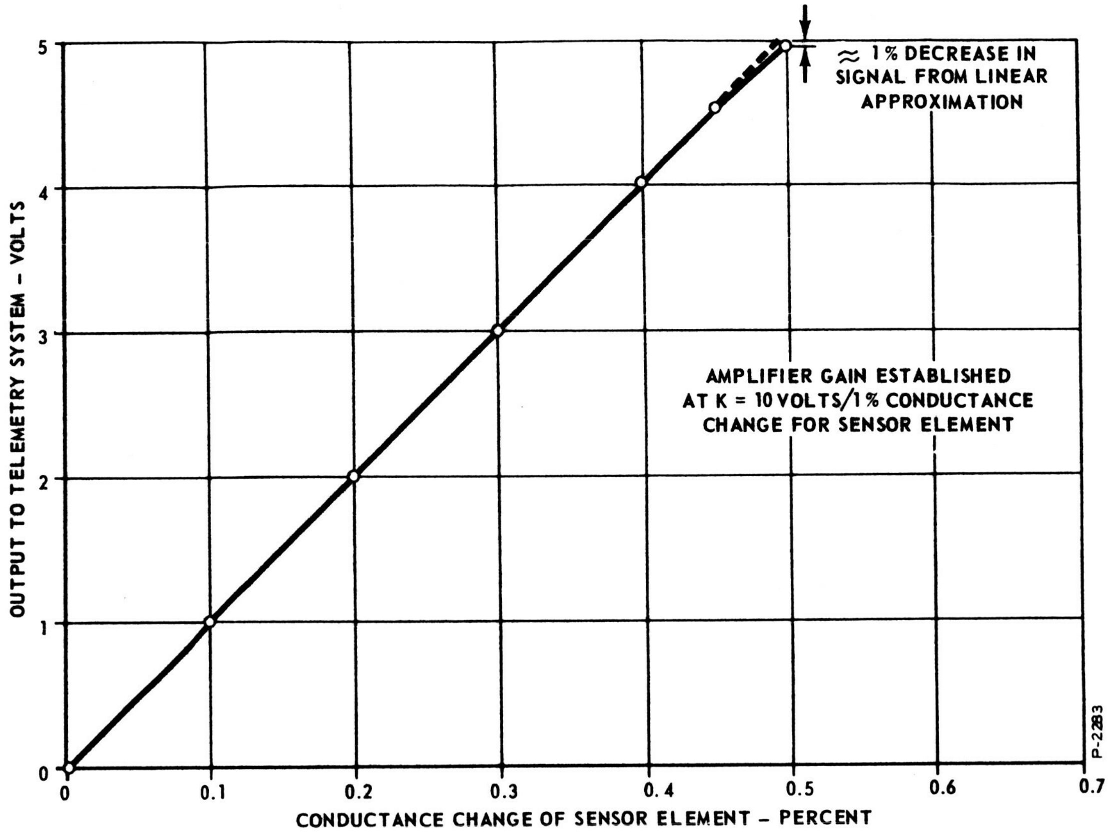

Figure 3-3 - Conductance Monitor Calibration Curve

3.3.2 Calibration Curves - Hydrogen Gas

Prior to shipment, the two prototype hydrogen detectors, S/N 102 and S/N 103, were calibrated for hydrogen sensitivity in a nitrogen ambient gas at normal pressures. The calibration curves are shown in Figures 3-4 and 3-5. On these curves, the hydrogen detector output signal, in volts, is plotted against the hydrogen partial pressure, in Torr, drawn to a $P_h^{0.53}$ scale. Both curves exhibit a slight upward curvature instead of being linear as was expected (based on earlier measurements with other sensor elements from the P-102 set). This seems to indicate that the exponential slope of the pressure term for the aged sensor elements P-102-16 and P-102-18 is slightly higher than 0.53.

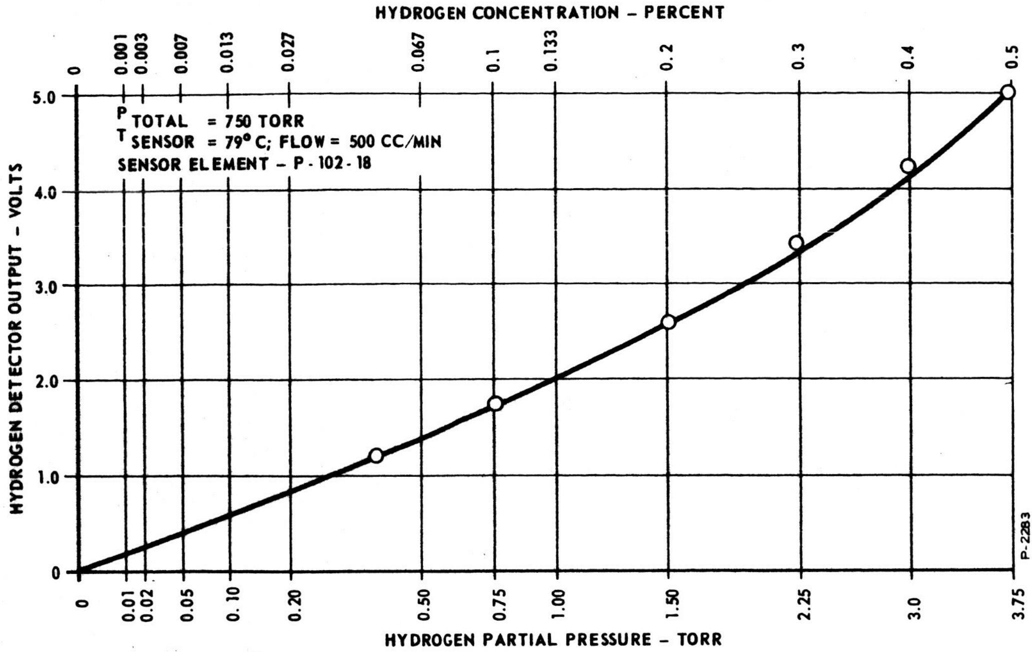

Figure 3-4 - Detector Set S/N 102 Calibration Curve (Hydrogen in Nitrogen Carrier)

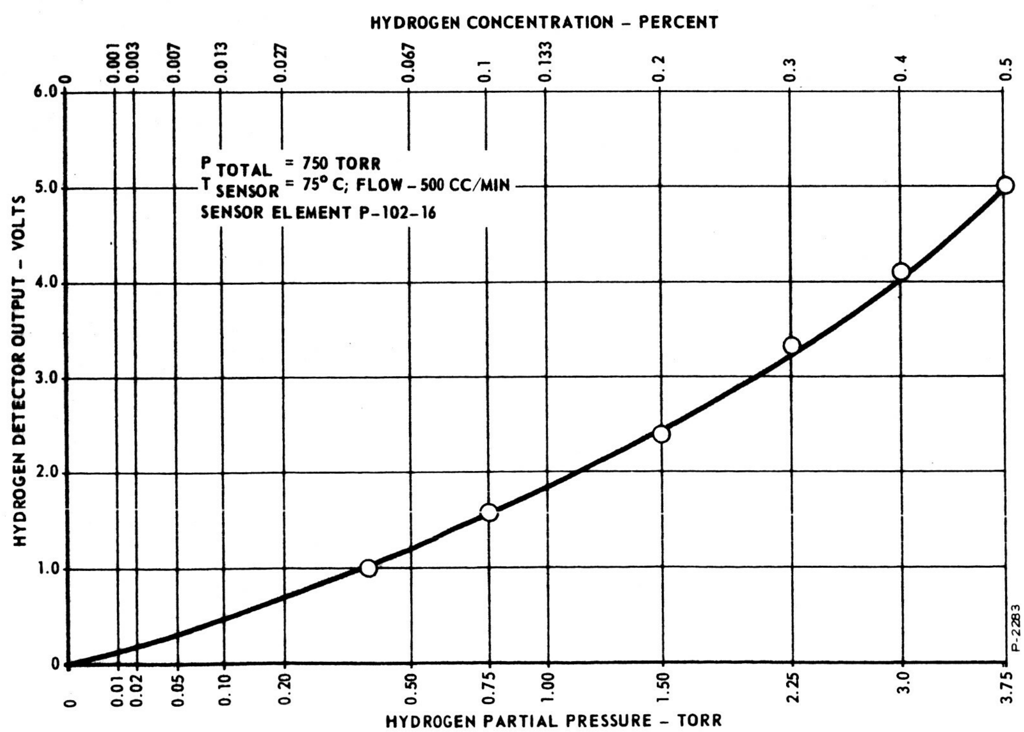

Figure 3-5 - Detector Set S/N 103 Calibration Curve (Hydrogen in Nitrogen Carrier)

3.3.3 Output Signal Characteristics

The output of the hydrogen detector is a voltage which ranges from 0 to 5 volts dc and is closely related to the sensed hydrogen partial pressure by the expression

$$E_o = k_1 P_h^{\alpha} \quad ,$$

where

E_o is the output voltage in volts

P_h is the hydrogen partial pressure in Torr

α is the dimensionless exponential sensitivity and is approximately 0.53

and

k_1 is the porportionality constant and is approximately 2.5 for the above units designations.

The calibration curves for the two prototype hydrogen detectors, for outputs between 0 and 5 volts dc, is shown in Figures 3-4 and 3-5. For output voltages above 6 volts, the output is attenuated to prevent overloading the telemetry channel. A positive signal transmission characteristic for the output limiter is shown in Figure 3-6. Negative polarity output signals (due to possible equipment malfunction) are clipped at approximately -0.6 volt dc.

In order to prevent circulating ground currents in the telemetry system, the hydrogen detector output circuitry, shown in Figure 2-6 , is completely isolated from ground. In addition, differential noise pickup is minimized by providing an output impedance which is equivalent to the parallel combination of a 15-microfarad capacitor and a 1,100-ohm resistor. This low output impedance also reduces signal attenuation to much less than one percent when a standard high level telemetry system is employed.

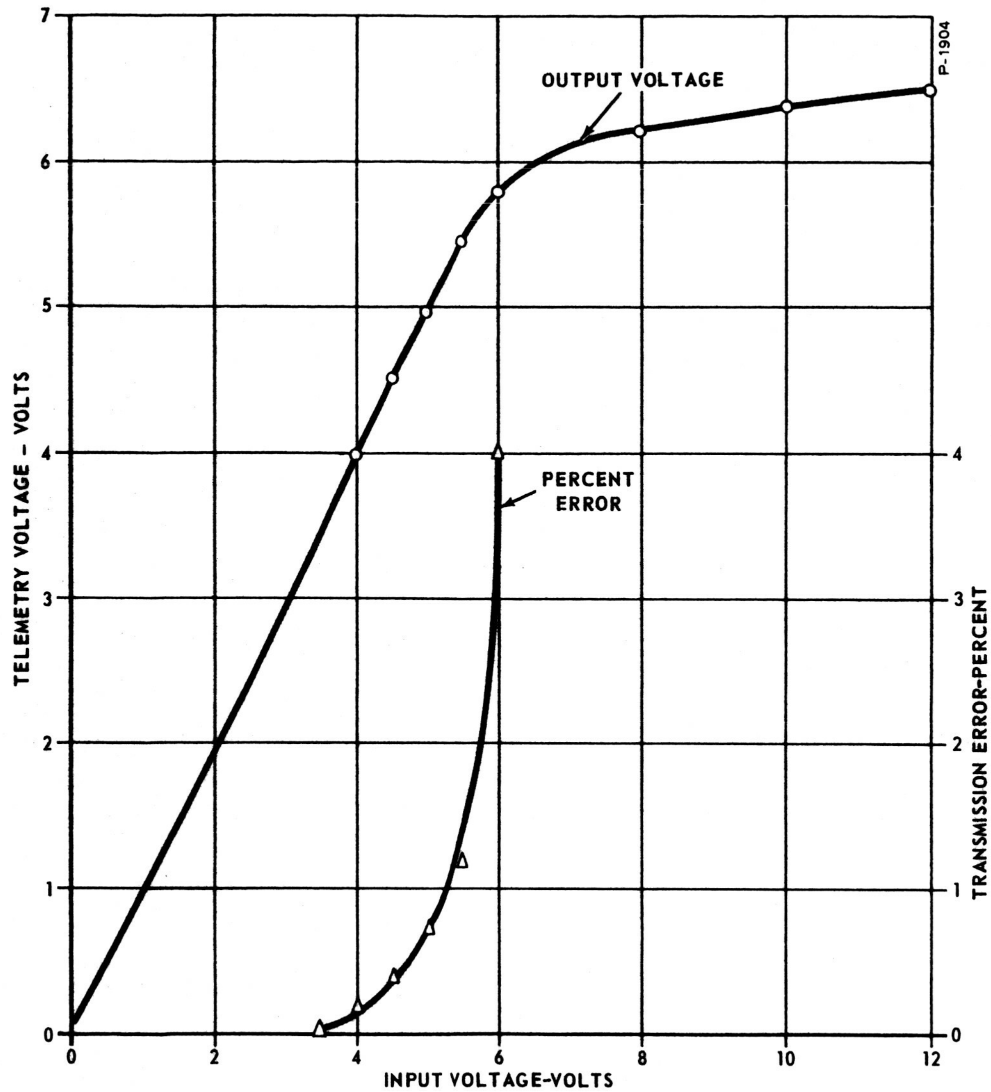

Figure 3-6 Limiter Transmission Characteristic

3.3.4 Sensor Element Temperature Range

The breadboard and prototype hydrogen detectors have been delivered with a preset sensor element temperature control point of approximately 75°C. This temperature is a compromise selected for stable long term operation and reasonable response times. The operating temperature can be adjusted to different values, if desired, by changing the value of the temperature control resistor. The procedure for making this change is discussed in Section 4.

The maximum sensor element temperature rise above ambient, at normal pressure, is approximately 175°C, with the listed 160-ohm heater and the 2N697 switch transistor in the output of the heater control circuitry. Under vacuum conditions, where the major heat loss of the sensor element is by conductive flow to the mounting plate, the possible controlled temperature rise above ambient will be in excess of 300°C.

All elements in contact with the heater element and sensor element are capable of operating for extended periods at temperatures up to 125°C. Operation at higher temperatures is permissible for short periods but is not recommended without modifying the sensor assembly design.

3.3.5 Power Requirements

The prototype hydrogen detectors are designed to operate from a nominal 28 ±3 volt line. Operation at voltage levels as low as 21 or as high as 35 volts is possible for short periods of time without significant effect on performance. There is danger of component thermal overload, however, at the higher voltages under vacuum conditions; therefore, such operations should be limited to brief test periods.

The supply current drain from a 28-volt line is listed below for a number of conditions:

1. Start up at standard temperature and pressure conditions, with motor and heater on:

   $$I_s \approx 400 \text{ ma}$$

2. Steady state operation at standard temperature and pressure conditions; sensor element at 75°C:

   $$I_s \approx 275 \text{ ma}$$

3. Steady state operation at standard temperature and pressure condition; sensor element at 75°C; blower off:

   $$I_s \approx 130 \text{ ma}$$

4. Steady state operation at standard temperature and pressure conditions; sensor element at ambient temperature; blower off:

   $$I_s \approx 75 \text{ ma}$$

5. Steady state operation under high vacuum condition; sensor element at 75°C; blower off:

$$I_s \approx 95 \text{ ma}$$

For operation at a sensor element temperature different than 75°C, there will be an increased current requirement of approximately 1 ma for each degree Centigrade increase in element operating temperature. If the blower is turned off, the increase will be somewhat less.

3.3.6 Weight

The weights of the breadboard detector (not foam encapsulated) and the two prototype detectors are listed on a subcomponent basis in Table 3-1.

Table 3-1 - Subcomponent Weights

Item	Breadboard SN 101	Prototypes SN 102	SN 103
Control Assembly	27.5 oz	29.75 oz	30.75 oz
Sensor Assembly and Cable	9.0 oz	9.0 oz	9.0 oz
Total Weights	2 lb 4.5 oz	2 lb 6.75 oz	2 lb 7.75 oz

3.4 SUMMARY OF SYSTEM CHARACTERISTICS

The thin film palladium sensor element in its present state of development has been shown to be capable of sensing hydrogen under an extremely wide range of ambient pressure levels. It does not, however, meet all of the conditions listed in the target specifications of Contract NAS 8-5282. These limitations are pointed out in subsection 3.2.

The control electronics are not only completely compatible with the present sensor elements, but sufficient flexibility and stability have been incorporated in their design such that they will be usable with second generation detection elements which have greatly improved performance capabilities.

Both the thin film palladium sensor element and the control electronics contribute to the system's performance characteristics. Table 3-2 compares the area hydrogen detector performance characteristics as listed in Contract NAS 8-5282. For those characteristics which have been measured at the Research Laboratories Division, the specific results are listed. For those characteristics which were used as design goals but measurements not made, comments are added as to the expected performance which would result under the listed conditions.

Table 3-2 - Comparison of Performance Characteristics

Characteristic	Design Specification	Measured Characteristic
A. Ambient Pressure	760 mm to 10^{-8} mm of Hg	Non-operating: 760 mm Hg to 10^{-6} mm Hg; No damage or other adverse effects. 10^{-6} mm Hg to 10^{-8} mm Hg; Not measured. No adverse effects expected. Operating: 760 mm Hg to 10^{-3} mm Hg; Performance as specified below. No degradation due to pressure. 10^{-3} mm Hg to 10^{-6} mm Hg; No useful performance with present sensor elements. No equipment degradation due to attempted operation at low pressure. 10^{-6} mm Hg to 10^{-8} mm Hg; Not measured. No adverse effects expected.
B. Ambient Temperature	+60 to -150° Celsius	Non-operating: -20°C to +75°C; No damage. -150°C to -20°C; Not tested. No adverse effects expected. Operating: -20°C to +75°C; Normal operation. -150°C to -20°C; Not tested. Possible difficulty of dc-dc converter start after cold soak at low temperature. Once started, no difficulties anticipated for vacuum environment.
C. Vibration	0-2000 cps; 35 g's Random noise, 15 minutes in each of three mutually perpendicular planes	Not tested. Difficulties not expected for electronic control assembly. Possibility of blower motor bearing failure in sensor assembly.
D. Sensitivity	Ten parts per million of hydrogen in air	Sensor element is responsive to hydrogen partial pressure not concentration ratio. Sensitivity limit is about 10^{-3} Torr. Hydrogen concentration limit is about 1 part per million in non-oxidizing gases at STP, 1000 parts per million in air at STP.

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Table 3-2 - Comparison of Performance Characteristics (Cont'd)

Characteristic	Design Specification	Measured Characteristic
E. Accuracy	Five percent of actual gas concentration	Ten percent of indicated hydrogen pressure plus oxygen offset, which is equivalent to between 0.01% and 0.5% of oxygen pressure.
F. Range	Ten parts per million to 5000 parts per million (wide range is desirable)	Equipment range set for 1 part per million to 5000 parts per million at STP. (Essentially a square root scale to extend response indication.)
G. Output Signal	Analog output proportional to quantity of hydrogen (0-5 volts dc desired)	Zero-5 volts dc with ground system isolation. D-C signal is proportional to hydrogen pressure raised to the 0.53 power; desired for extended range.
H. Response Time	500 milliseconds or better	500 milliseconds or slower; response time, (0-10%), is inversely proportional to square root of hydrogen pressure.
I. Stability	The system must be capable of continuous operation and must maintain calibration curve to ± 1% for eight (8) hours without adjustment	The equipment is capable of continuous operation and will typically remain calibrated to within ± 20% for eight hours with present film elements.
J. Power Available	28 volts dc.	Requires 28 ± 5 volts dc.
K. Physical Dimensions	The latest miniaturization techniques should be used to produce a compact, explosion proof package.	Control assembly is a 4" x 2.5" x 3" box on a 3.00" x 5.31" base. Sensor assembly is 1.6" x 1.0" x 1.0" mounted on a 1.00" x 2.24" base. Interconnecting cable is 1/2" diameter 5' long. Terminal board construction is employed with all hard wiring connections. Entire control assembly is internally enclosed in silicone foam resin.
L. Weight	The total system weight should not exceed 3 lbs.	The system weight, for the delivered sensors, each containing a control assembly, sensor assembly and interconnecting cable, are as follows: SN 101 2 lbs 4.5 oz SN 102 2 lbs 6.75 oz SN 103 2 lbs 7.75 oz
M. Detector Specificity	The sensor shall not respond to any other gas so that output from the sensor will be an indication of the presence of hydrogen.	The measured response to saturated vapors at STP were obtained for the following materials: Acetone — No effect Benzene — No effect Ethyl Alcohol — No effect Freon, P. C. — No effect Methyl Alcohol — No effect RPI Fuel — No effect Toluene — No effect Water — No effect Argon — Little effect Helium — No effect Nitrogen — No effect Oxygen — Interference; see text subsection 3.2.3

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SECTION 4

INSTALLATION AND MAINTENANCE

4.1 DESCRIPTION OF EQUIPMENT

The prototype area hydrogen detector is capable of quantitatively detecting low concentrations of hydrogen gas over an extremely wide ambient temperature and pressure range. It consists of two major units; the sensor assembly and the control assembly. They are electrically interconnected by a five foot multiple conductor cable which is a permanent part of the sensor assembly.

The basic hydrogen sensing element is a thin palladium alloy film deposited on a glass substrate. It is contained in the sensor assembly and operated at a constant temperature.

The control circuitry employs all silicon semiconductor components -- compactness and electrical efficiency were major design considerations. Stable performance, under widely varying conditions of temperature, pressure, vibration, and line voltage, have been assured by operating all functional stages either in a switch mode (transistors are either cut-off or conducting in saturation) or within a high gain feedback amplifier loop.

A complete set of electrical schematics, mechanical engineering drawings, and component parts lists are included in Section 6 of this report. Photographs of the sensor and control assemblies will be found in Section 2, and photographs of the circuit cards in subsection 4.4.

4.2 INSTALLATION AND OPERATION

4.2.1 Location of Subassemblies

Each of the prototype area hydrogen detector subassembly units will function normally in any orientation with respect to a gravitational field, acceleration vector or vibration vector. The location and orientation of the sensor assembly however, does have a strong influence on how well a potential hydrogen gas leak can be monitored.

At normal (760 Torr) pressures and when in a gravitational field, hydrogen gas emerging from a leak will form a hydrogen rich mixture in the vicinity of the leak. This mixture, having a lower density then the ambient gas, will quickly rise. Thus, in order to quickly detect the emerging gas, the sensor assembly should be located "above" the potential leak areas. In a normal pressure regime, the blower motor will effectively sample the surrounding gas for any orientation of the sensor assembly.

At very low ambient gas pressures, where the molecular mean free path lengths are comparable to the physical dimensions of the area to be monitored for hydrogen gas, the gravity or inertial force vectors will not significantly affect the distribution of leaking hydrogen gas. Under these conditions, the location and orientation of the sensor assembly should be dictated by line-of-sight considerations.

The direction of maximum sensitivity of the sensor assembly lies in a direction normal to the plane of the sensor film elements. It decreases in proportion to the cosine of the deviation angle from the normal, up to about 45 degrees. Beyond 45 degrees, the edge shadow effects cause the sensitivity to decrease at a greater rate.

The filter pack should not be employed if operation at very low pressures is required, since it greatly increases the systems response time and decreases sensitivity. At normal pressures, the filter module can be used to prevent contamination, particularly by oil vapors, without appreciably affecting the sensitivity or time constant of the detector system.

4.2.2 Mechanical Requirements

The sensor assembly is designed to be mounted on a flat plate by two No. 8 machine screws. The hole separation is nominally 1.80 ±0.15 inches.

The control assembly is designed to be mounted on a flat plate by four No. 8 machine screws arranged on a rectangular pattern. The hole pattern has a width of 1.50 ±0.01 inches and length of 4.85 ±0.15 inches. The control assembly must be mounted within 5 feet of the sensor assembly so that they can be connected by the 5-foot interconnecting cable.

For further reference to the structural details of the sensor and control assembly mounting plates, refer to the Engineering Drawings B2154564 and C2153561, respectively, in Section 6.

4.2.3 Electrical Requirements

The area hydrogen detector is designed to provide normal operation with as few as four interconnection wires to the vehicle control system. Two wires are required for the isolated (floating) output signal, one for the +28 volt power, and one for the power return.

Both the control assembly and sensor assembly support plates and cases are electrically isolated from the power supply system. They may, however, be connected to either polarity of the supply system if desired. If this is done the amount of noise induced into the low level portion of the conductance monitor can be changed, and thus necessitate a new bridge balance adjustment.

Although only the four interconnections described above are required for normal operation, others can be used to provide installation or flight diagnostic data. There is one line that can be used to turn the blower motor either on or off. Two other lines enable a system calibration to be performed at 10, 90, and 101.5 percent of full scale.

All connections to the area hydrogen detector are made through a Bendix Pygmy connector type SP02E-12-10S. Typical connector wiring diagrams are shown in Figures 4-1 and 4-2.

The particular calibrate mode used in the prorotype area hydrogen detector depends upon whether or not +28 volts is applied to pins C and/or D of the power connector. If the pin D connection is opened, a 10 percent of full scale output change will be produced. If the pin C connection is opened, a 90 percent of full scale output change will be produced. If the connections to both pins C and D are opened a 101.5 percent of full scale output change results.

The blower motor can be turned off by connecting pin E of the power connector to the negative side of the 28 volt power supply system. The switch current is under 0.5 milliampere when closed, and the switch voltage is less than 5 volts when opened; thus, it can be reliably operated by a set of light duty contacts, such as those found in sensitive barometric pressure switches.

4.2.4 Operation

After installation, the area hydrogen detector is energized by turning on the 28 volt power. The equipment warm-up time is very

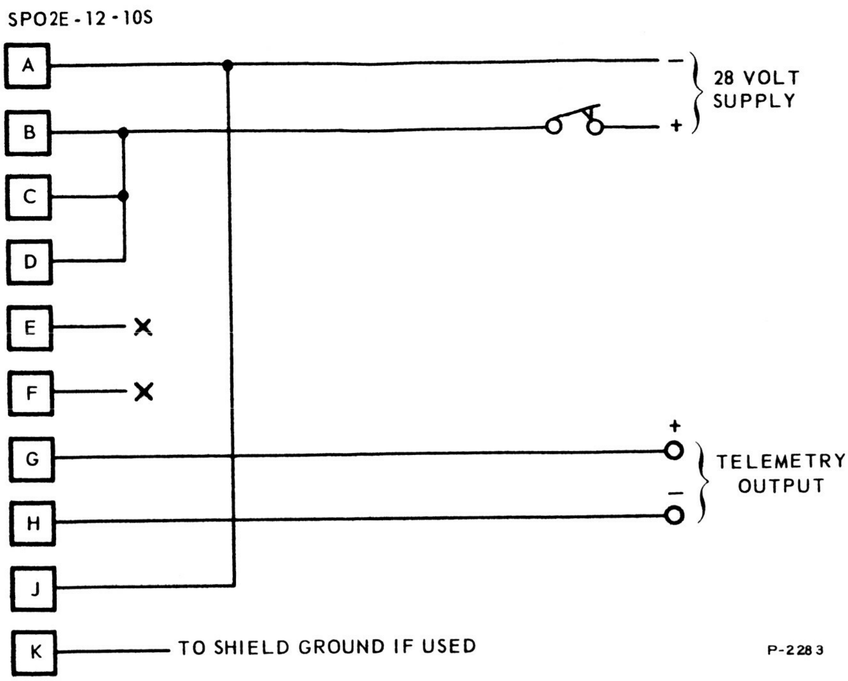


Figure 4-1 - Four Wire Interconnection Diagram

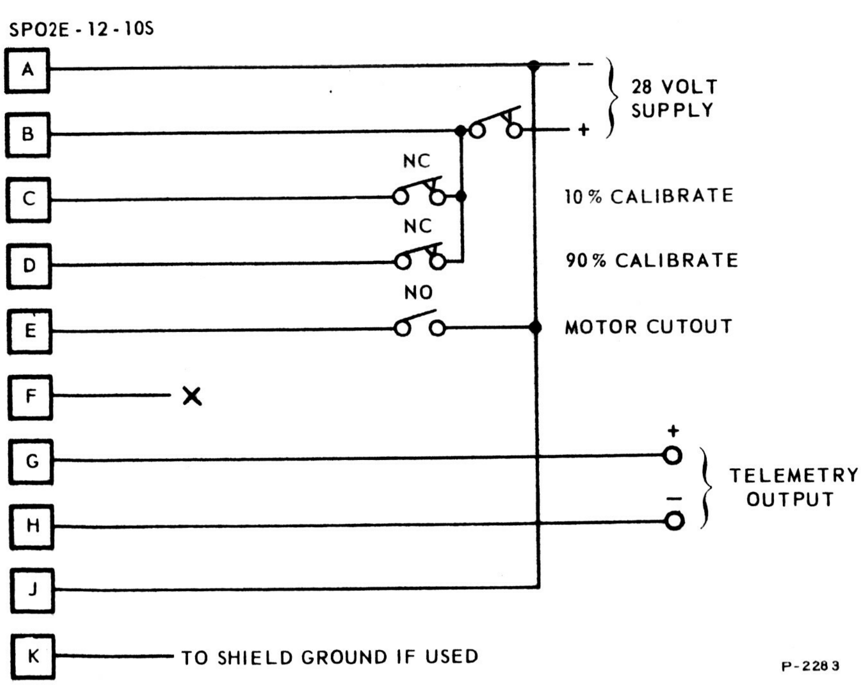


Figure 4-2 - Complete Control Interconnection Diagram

short usually less than 5 seconds, this being due largely to the blower motor inertia and the thermal time constant of the heater system. During the warm-up time, the current drain from the 28-volt power supply is approximately 400 ma. After warm-up, the current drain will drop to a steady-state level dependent upon the ambient temperature and pressure. The input power levels are discussed more fully in subsection 3.3.5.

4.3 ADJUSTMENTS

After replacing a sensor element with a new one which may have a slightly different resistance or sensitivity, the bridge detector circuitry and amplifier gain should be adjusted. Since the calibration circuitry levels are also dependent upon the sensor element resistance, they too might have to be adjusted. These adjustments should be checked and if required made in the following sequence: 1) balance adjustment, 2) gain adjustment, and 3) calibrate adjustment.

The three adjustment potentiometers are all accessible from the top of the control assembly. To reach them, the four cover screws are removed and the cover lifted off. Their location is shown in Figure 4-3.

4.3.1 Balance Adjustment

The area hydrogen detector is turned on and allowed to warm-up at least ten seconds. Then monitor the normal detector output, pins G and H of the power connector, with a 5-volt high input impedance meter (20,000 ohms/volt or greater). With the sensor assembly in a hydrogen free environment, vary the balance adjustment until the detector output reads zero. The adjustment is now complete and will not have to be made again.

4.3.2 Gain Adjustment

After making the balance adjustment, the sensor assembly is exposed to a sample gas containing 0.5 percent hydrogen. The amplifier gain adjustment is then varied to produce a 5-volt detector output. Refer to Figure 4-3 for the location of this potentiometer. Like the balance adjustment, readjustment is not required.

4.3.3 Calibration Adjustment

The calibration adjustment is made after both the balance and amplifier gain adjustments. The sensor assembly is operated in

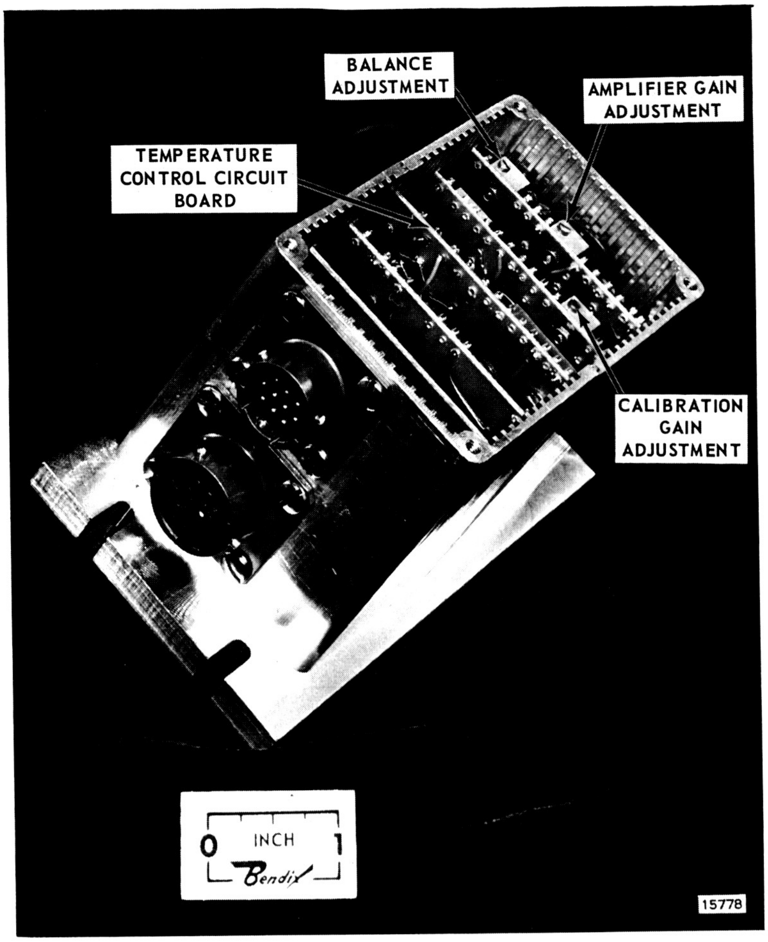


Figure 4-3 - Control Assembly with Cover Removed

hydrogen free gas. If the balance adjustment has been made properly, the detector output will be zero. Under these conditions, open the high calibrate switch (or disconnect pin C from the +28-volt line which is connected to pin B of SP02B-12-10S, if a high-calibrate switch is not provided), and vary the calibrate adjustment, Figure 4-3, to produce a 4.5-volt output signal. Upon closing the high-calibrate switch, the output level should drop to zero.

To check the low-calibrate level, open the low-calibrate switch (or disconnect pin D from the +28-volt line, pin B of SP02E-12-10S). The output should read approximately 0.5 volt. This level is automatically set at one ninth of the high-calibrate level by means of an internal a-c divider system. There is no independent adjustment, hence if 0.5 volt is not obtained, it indicates either a faulty calibration

system or a non-linear amplifier. In either case the detector should be serviced.

4.3.4 Sensor Temperature

The sensor temperature for the breadboard hydrogen detector and both prototype units was set at approximately 75°C. It is possible to vary the operating temperature, if desired, by substituting a different valued resistor for R308 (normally 47 K ohms) on the temperature control board. The appropriate resistance for R308 to provide a particular operating temperature within the range of 25°C to 125°C can be determined from the adjustment chart, Figure 4-4.

It is a difficult to make this substitution in the prototype area hydrogen detectors because of the silicon foam encapsulant, hence it is recommended the following procedure be closely followed in making the change:

1. Remove the four 6-32 socket-head screws which hold down the cover of the control assembly.
2. Remove the cover by pulling directly away from the assembly.
3. Remove the four 8-32 socket-head screws which hold the two chassis shells to the mounting plate.
4. Remove the mounting plate.
5. Remove the rear mounting shell (the shell without the connectors). This can be done by sliding it off the foamed core in a direction parallel to the internal groves. The silicone rubber foam might tend to adhere to the shell wall but the adhesive forces are very weak.
6. The temperature control resistor R308 is located at the bottom surface of the temperature control board. Refer to Figures 4-3 and 4-5 for location.
7. To obtain easy access to R308, carefully slit the silicon rubber foam between the component side of the temperature control board and the back of the adjacent board (reference generator board), with a sharp knife. The cutting should be done from

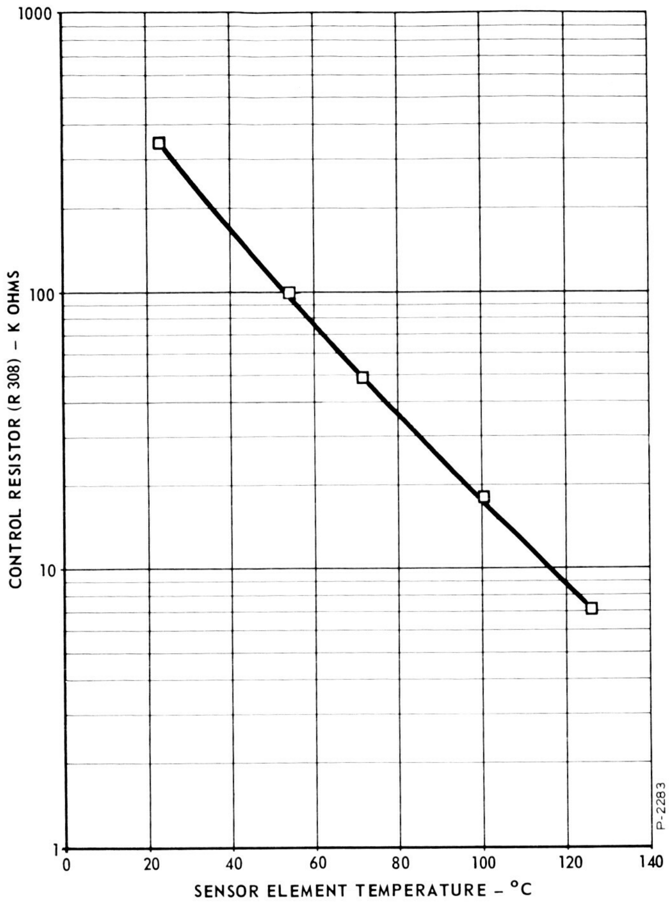


Figure 4-4 - Sensor Element Operating Temperature - Adjustment Chart

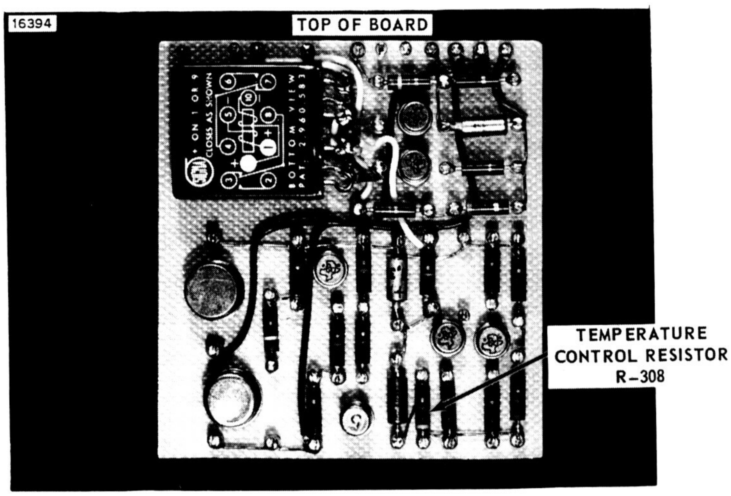


Figure 4-5 - Temperature Control Circuit Board

the bottom (support plate end) of the foamed package, and extend about 75 percent to the top --- a cut of about 2 inches.

8. Fold the two potted halfs back to make the component side of the temperature control board accessible.

9. Pull the foam away from the bottom of the board, to completely expose R308.

10. R308 can now be removed, using a low power soldering iron to melt the solder at the support terminals. It should be noted that these are slotted top terminals and the component is simply dropped into the slot without any lead bending.

11. Select the desired value for R308 from the adjustment chart, Figure 4-4.

12. Clip the ends of the resistor to within 1/8-inch of the body, and solder in place.

13. Place the two halves of the foamed circuit section together, slip on the rear shell, and replace the cover to hold the shells tightly together.

14. If desired, the patched section can be repotted using the Dow Corning Type S-5370 Silicon Rubber Foam. This material foams, and sets at room temperature within 3 minutes after mixing. After mixing, according to the directions, pour one or two cubic centimeters of the material before it has foamed, into the cavity left by the repair. Then, before the foaming has been completed, replace the support plate. This will cause the expanding foam to flow into the slit section and cavity, and effectively cement the structure together without any void spaces.

4.4 SERVICE NOTES

The following sections provide instructions for the assembly and replacement of various components of the area hydrogen detector. The directions given represent useful practices formulated during the latter four months of the development program. They are subject to

modification and improvement and should not be construed to be necessarily the best techniques that are likely to be devised.

4.4.1 Replacement of Sensor Element

1. If the filter module has been added to the sensor assembly, it should first be removed. Directions for doing this are given in subsection 4.4.2.

2. Remove the four 2-56 jam nuts holding the sensor assembly filter cover. They are part No. 12 on the sensor assembly Engineering Drawing D2153341.

3. Remove the cover by lifting straight up. This will expose the sensor element assembly.

4. Unsolder the three 0.006 inch diameter wires at the point where they are attached to the tab portions of the sensor element assembly.

5. Remove the two strips of tape from the glass-epoxy support plate assembly (Item No. 4 of D2153351). The sensor element assembly can now be lifted out of the support plate assembly channel by the two tape pieces.

Figure 4-6 - Packaged Area Hydrogen Detector Sensor Element

6. Remove the new sensor from the package (Figure 4-6) and center the sensor element assembly on top of the heat diffusion plate in the support plate assembly channel.

   Make certain the two-tab side of the sensor element assembly is touching the strip spacer (part No. 3 on the "Plate, Support Assembly" Engineering Drawing B2153348).

7. Tape the sensor element assembly to the support plate assembly, similar to the way in which the original sensor element assembly was taped. The tape sections are 1/8-inch by 1/2-inch sections of a 0.002-inch thick "FEP-TEFLON" tape, sold by the Connecticut Hard Rubber Company. They serve a dual purpose: one, they hold the sensor assembly in place for soldering, and two, they provide an insulating layer between the three 0.006-inch diameter leads and the end of the heat diffusion and other conductive elements.

8. Solder the three lead wires to the appropriate terminals of the sensor element assembly, as shown on Engineering Drawing D2153341. A low melting point solder should be used, such as "Indalloy Intermediate Solder No. 7," to prevent stripping the sensor and reference elements from the glass substrate.

9. Replace the cover.

10. Replace the four 2-56 jam nuts to hole the cover down

4.4.2 Filter Module Removal

The filter module can be removed as a complete module by unloosening the four socket head cap screws which have their heads on top of the filter module. (Part No. 7 of the Engineering Drawing, C2153676 "Area Hydrogen Sensor Filter Assembly"). These screws are locked into the filter cover assembly and cannot be separated from the cover.

Each screw should be unscrewed about one-half turn following an orderly sequence, such as clockwise around the cover. This sequence is repeated until the filter module is freed from the sensor assembly. The action of unscrewing these screws will lift that corner of the filter module holding the screw a little bit, consequently distorting the cover. If an attempt is made to remove one screw at a time, the cover will be cracked.

The assembly procedure described in subsection 4.4.4 required the fastening of the spacer filter to the cover with a silastic adhesive if this technique has been used the filter module can be disassembled in any position. The prototype sensor assemblies, SN/102 and SN/103, did not employ adhesive, however, and the spacer filter is not firmly fastened to the filter assembly. When disassembling these units for the first time, hold the sensor assembly upside down to keep the carbon granules in the filter cover. After disassembly, the filter units can be modified as per steps 15 through 18 of subsection 4.4.4.

After removing the filter module, the loose cover should be fastened to the sensor assembly by threading four 2-56 nuts onto the exposed studs and tightening securely.

4.4.3 Addition of Filter Module

When the filter module is prepared as suggested in subsection 4.4.4, it can be handled in any position without losing the activated carbon granules. The following directions assume this preparation:

1. Remove the four 2-56 jam nuts from the top of the sensor assembly. Store for future use.
2. Place the filter module directly on top of the sensor assembly. The four filter module standoffs, which are just visible in the corners of the modules, should be centered on the four studs of the sensor assembly.
3. Tighten the four screws in an orderly sequence (such as clockwise around the filter assembly) turning each screw only 1/2 turn at a time.
4. Continue to tighten all four screws until the filter module is seated directly on top of the sensor

assembly cover. Avoid overtightening as this can crack the cover. The assembly is now complete.

4.4.4 Replacing Activated Carbon in Filter Module

The frequency with which the filter module filling should be replenished has not been determined. For normal clean air environments, such as is typical of an electrical test laboratory, a 1000 hour operating time seems reasonable. For environments which are extremely dusty or contain oil fumes, more frequent changing is recommended.

In the following replacement directions, it will be useful to refer to the Engineering Drawing C2153676, "Area Hydrogen Sensor, Filter Assembly."

1. If the filter module is attached to the sensor assembly, it should be removed as per subsection 4.4.2.

2. Holding the filter module with the screw heads down, pry off the bottom gasket and perforated metal spacer. These two pieces can be separate or they can be attached to one another with a film of silicon rubber. (There is no need to separate the two pieces from one another.)

3. Remove the cloth filter and discard.

4. Dump out the granulated carbon filling and discard.

5. Remove the top cloth filter and discard.

6. Remove the top perforated metal filter spacer.

7. At this point the four socket head screws should be fastened to the stainless steel standoffs through the filter cover. There should be just enough play for the metal assembly to turn without binding. If the screws are not fastened securely to the standoff sections, remove them from the cover. If they are securely fastened, leave them on.

8. Wash the cover, screws, standoffs, metal filter spacer, and gasket in an oil cutting solvent such

as clear MEK or acetone. Shake off excess and dry thoroughly.

9. If there are any loose screw-standoff assemblies, apply locktite to the screws, assemble through the cover so the assembly is snug against the cover but still free to turn, let set 15 minutes; then rewash in acetone.

10. Holding the filter assembly with the screw heads down, insert the upper perforated metal spacer.

11. Insert a clean cloth filter element.

12. Add fresh activated carbon to within 1/32 inch of the cover lip.

13. Insert a new bottom cloth filter element.

14. Insert the bottom perforated metal filter spacer and press down to provide a flush fit with the bottom of the cover. Remove or add carbon granules to produce the flush fit.

15. Add a drop of silastic adhesive, such as Dow Corning Type 732, on each side of the cover at edge of the metal filter spacer.

16. Add the silicone rubber gasket. The gasket should contact the adhesive which will hold the gasket, metal filter spacer, and cover together.

17. Tamp on a flat surface to make sure the gasket is flat across the bottom of the filter module.

18. Invert the module, and let the silastic adhesive cure at least 12 hours before use.

4.4.5 Test Cable

A test cable was provided with the Breadboard Area Hydrogen Detector to assist in the laboratory testing of that unit. It will also mate with both prototype detectors and can be used for the same purpose. Figure 4-7 identifies the connector pin-wire color coding and also suggests those control functions which can be provided.

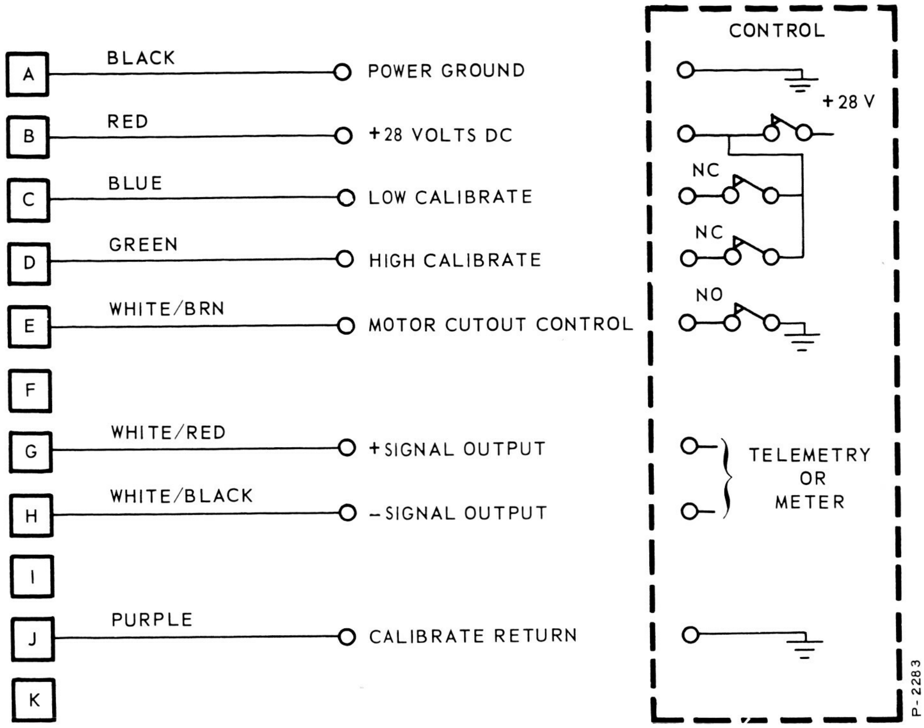


Figure 4-7 - Test Cable Interconnection Diagram (SPO2E-12-10 S)

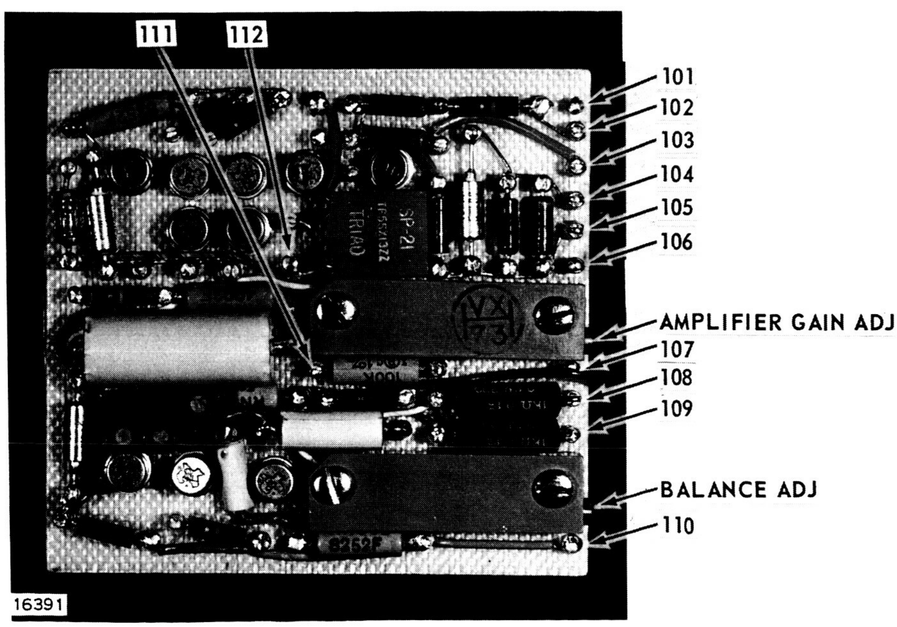


Figure 4-8 - Bridge Amplifier Circuit

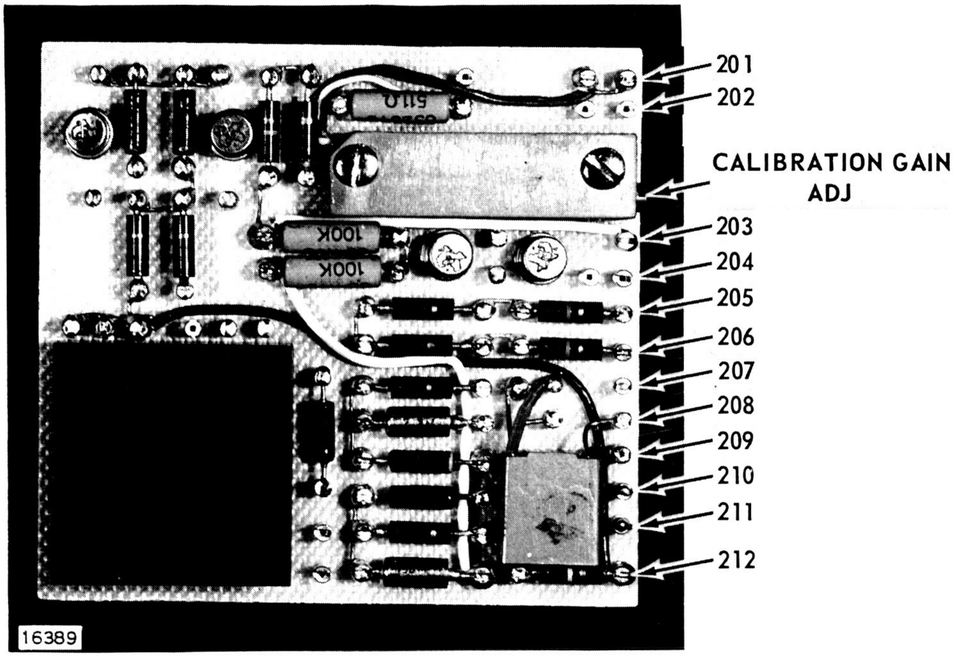


Figure 4-9 - Reference Generator

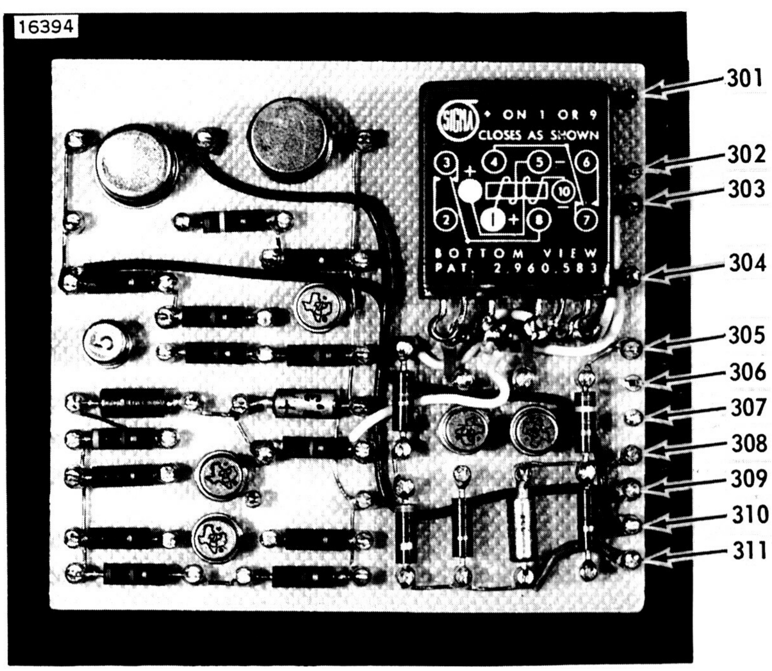


Figure 4-10 - Temperature Control Circuit Board

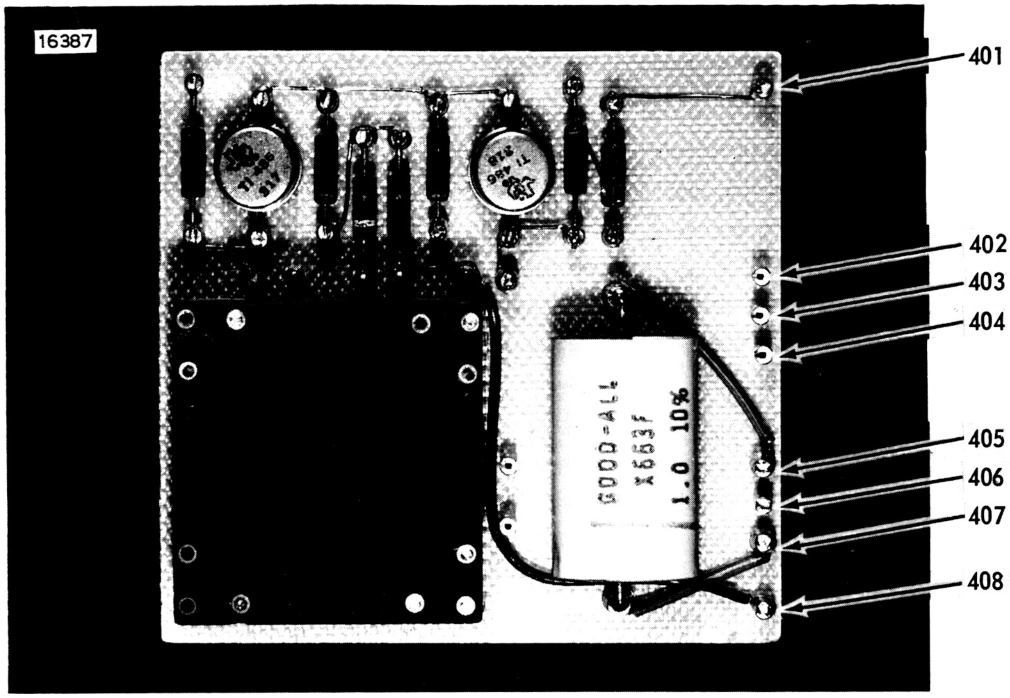


Figure 4-11 - Fan-Motor Dirve Circuit

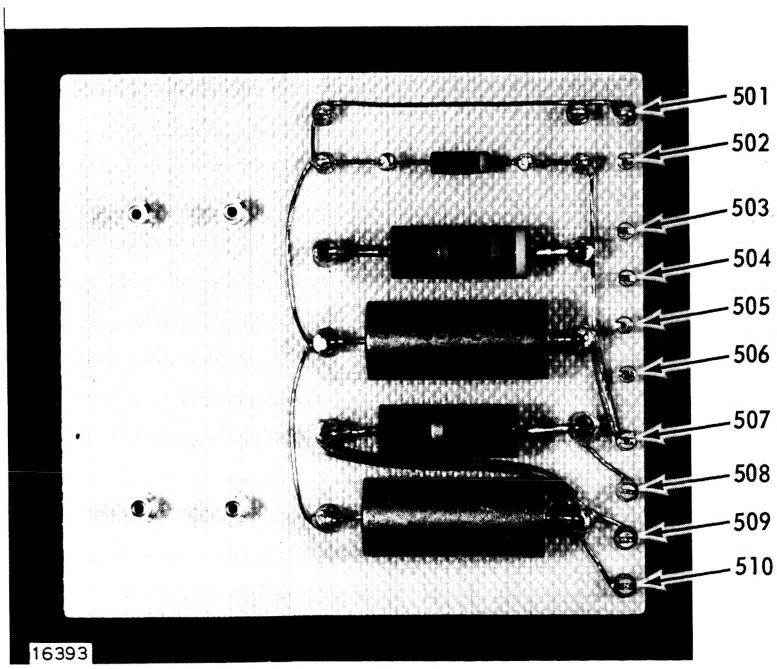


Figure 4-12 - Power Supply Circuit Board

4.4.6 Identification of Card Terminals

All interconnections between the five circuit boards and the two connectors of the control assembly are made from split lug terminals located at the top edge of the circuit boards. These terminals can be used for diagnostic servicing of the control assembly if the need arises. They are accessible from the top of the control assembly without removing the silicon rubber foam.

Each end terminal on all five circuit cards, is identified by a location number. Those numbers are shown in Figures 4-8 to 4-12 and are further identified on the electrical schematic of the control assembly, engineering drawing D2154864.

SECTION 5

RECOMMENDATIONS FOR FUTURE WORK

5.1 GENERAL

The work completed in developing the thin film palladium hydrogen detector system under contract NAS 8-5282 has indicated several methods by which the performance of the film element can be significantly improved. These methods have been reviewed and those which afford the greatest promise and are directly applicable to the detector already developed are discussed below along with the work effort required to develop and evaluate these techniques.

5.2 PROPOSED WORK PROGRAM

5.2.1 Scope and Objectives

This effort is directed toward:

(a) Increasing detector stability

(b) Lowering the hydrogen concentration level at which the sensor just becomes responsive (threshold level)

(c) Decreasing sensor response time

5.2.2 Method of Approach

5.2.2.1 Detector Stability

The signal generated by the detector system is produced by a bridge circuit unbalance caused by a change in resistance of the sensor element with respect to the reference film. As a result, detector stability is a function of both sensor and reference film stabilities. Instability in the former is primarily due to absorption of O_2 present in the sampling gas; reference film resistance changes are produced by the diffusion of reactive gases (H_2, O_2) through its protective film. Consequently, stability can be improved by isolating the sensor film from O_2 and the reference film from both H_2 and O_2.

The sensor film can be isolated from O_2 by covering it with a deposited overlay of Au, Pt, or by some other precious metal, which does not react with O_2 and form an effective O_2 barrier, but yet remains permeable to H_2. Such metals as Al, Mg, and Ta can also be employed as overlay materials after suitable thermal or anodization conversion since these converted films are impervious to O_2. In a similar manner, the overlay technique can be extended to protect the reference film; in this case SiO, MgF, organic, and SiO-metal film overlays can be employed.

Experimental work must be carried out before barrier materials can be used effectively to increase stability. In the case of sensor film barriers, optimum overlay thickness must be empirically determined: an excessively thick barrier would afford O_2 protection but would prevent H_2 ingress; a thin barrier would not afford O_2 protection. Succeeding this determination, the effectiveness of each material must be evaluated through incorporation in a detector system. In addition anodization techniques for use with Al, Mg, and Ta will have to be explored with the objective of controlling formed film properties regarding discriminatory permeability to H_2 and O_2. In a similar manner, reference film overlay materials must be evaluated not only relative to shielding effectiveness but also regarding compatibility with Pd films.

5.2.2.2 Threshold Level

The level of H_2 concentration at which Pd first exhibits measurable changes in resistance is dependent upon several parameters associated with the Pd-H_2 reaction mechanism. In this reaction H_2 atoms are catalytically dissociated at active sites on the Pd surface; these atoms then migrate and ultimately penetrate the Pd lattice, producing lattice perturbations which increase resistance in direct proportion to the hydrogen concentration in the Pd. The amount of hydrogen absorbed consequently depends upon the ambient molecular hydrogen pressure, the density of activation sites, the rate of hydrogen atom recombination and reaction with other gases at the surface, and the rate of hydrogen desorption from the lattice. On the basis of this mechanism, the threshold level can be decreased by increasing the activation site density and decreasing the hydrogen atom recombination and desorption.

Current knowledge of the nature of active sites and methods of controlling their density and species is very limited. However, there is some evidence which indicates that catalytic activity, and hence site density, is closely associated with thin film surface stacking faults. Consequently, by varying the type and density of these faults, it may be possible to modify active site density in Pd films and thereby change their hydrogen threshold levels.

The density and species of surface faults in thin films is highly dependent on the method of deposition, deposition parameters, and post-deposition treatment. Films can be prepared by evaporation or sputtering which exhibit surface properties characteristic of the deposition process. Factors such as deposition rate, substrate temperature, type, concentration, and energy of sputtering ions considerably affect the surface lattice features of thin films. Film surface properties are also affected by thermal annealing and by bombardment of the film with energetic ions which disrupt the lattice surface ions.

All of these factors are potentially capable of modifying the properties of thin film sensors. However, it is not possible to predict which combination of factors and processes is capable of significantly reducing the H_2 threshold of Pd film sensors: experimental work must be carried out to evaluate these parameters.

The effective density of sites is also dependent upon the presence of contaminants such as oil and reaction products formed during film deposition: these contaminants become strongly bonded to activation sites and effectively neutralize them regarding further site interaction with H_2, thereby increasing sensor threshold levels. Similar "poisoning" reactions can occur after sensor deposition when the sensor is first exposed to air. These effects can be suppressed by employing an ultra clean (vac-ion, sorption pump) deposition station, carrying out deposition at very low pressures and by depositing protective overlays immediately after depositing the Pd film and prior to exposing the sensor to air. Up to now, this technique was unavailable because it requires a special vacuum station with an in-process mask changer jig.

On the basis of the above discussion, the following experimental effort should be carried out in order to improve the H_2 threshold level of thin film Pd films:

(1) Preparation and evaluation of films made by evaporation in which deposition rate and substrate temperature are varied over a limited range.

(2) Preparation and evaluation of films made by sputtering in which type, concentration and energy of sputtering ions is varied over a limited range.

(3) Evaluation of films that have been annealed at different temperatures in a variety of atmospheres.

(4) Evaluation of films that have been bombarded by energetic ions immediately after deposition.

(5) Evaluation of overlaid films (as in (a)) prepared in in a single vacuum step so that the interface is uncontaminated.

All of these films will be prepared in an ultra clean system at low pressures. The initial effort will be of an exploratory nature in order to determine which techniques have the most pronounced effect on sensor properties. Once this has been established, intensive work will be initiated to optimize these techniques. Finally, the optimized process will be used to prepare films for extensive evaluation.

5.2.2.3 Sensor Response Time

The time required for hydrogen atoms to permeate the Pd sensor film determines the response time of the detector. This constant is dependent on the effective rate of hydrogen atom generation, the surface mobility of hydrogen atoms and the rate at which they diffuse into the metal lattice. A comparison of analytical data with experimental data indicates that the hydrogen diffusion process plays a minor role in determining the sensor response time. Consequently, the rate of hydrogen atom generation and atomic hydrogen surface mobilities are believed to be the processes which limit sensor response time. Both of these factors are dependent upon the film surface properties. Methods of modifying this parameter were discussed in the section regarding threshold level, and methods of improving response time are similar and would be carried out concurrently with this effort.

5.2.3 Summary

The stability of thin film Pd hydrogen sensors can be significantly improved by depositing a thin film protective overlay on both the sensor and reference resistance films. Several materials and processing techniques offer promise for providing suitable overlays.

An experimental effort is required in order to determine which combination of material and processing technique is most effective in increasing stability. The experimental effort recommended for this evaluation has the following tasks, objectives and methods of approach:

Task I: Sensor Film Overlay Evaluation and Development

Objective: Evaluate materials and develop and optimize processing techniques for the deposition of thin film overlays on Pd sensor films that are permeable only to H_2.

Method of Approach: Precious metal and anodizable metal overlays on Pd films will be prepared in which metal and oxide thickness will be varied over a limited range. These films will be evaluated by monitoring the drift of these sensors when exposed to H_2 and air atmospheres. The most promising combination of material and technique will then be intensively investigated to obtain optimization.

Task II: Reference Resistance Film Overlay Evaluation and Development

Objective: Evaluate materials and develop and optimize processing techniques for the deposition of thin film overlays on Pd sensor films that are impervious to H_2, O_2, and N_2 and are compatible with Pd films.

Method of Approach: SiO, MgF, organic, and SiO-metal overlays will be deposited on Pd films. The effectiveness of these materials will be evaluated by monitoring sensor drift when exposed to H_2 and air. The most suitable barrier material will then be used for execution of Task III.

Task III: Evaluation of Detectors Protected with Thin Film Overlays

Objective: Evaluate the drift characteristics of sensors protected with optimum overlay materials.

Method of Approach: Sensors protected with the optimum overlay materials developed in Tasks I and II will be prepared and sensor drift characteristics will be evaluated when the element is exposed to H_2 and air.

The response time and threshold level of thin film Pd hydrogen sensors is dependent upon film fabrication parameters. The factors of greatest importance are deposition rate, substrate temperature, deposition vacuum level, post deposition surface bombardment, and annealing. It is recommended that these parameters be systematically investigated to determine which factors are most critical in modifying sensor response time and threshold level. Succeeding this evaluation effort must be directed toward optimization of these parameters. The work program recommended for this experimental effort consists of the following tasks, objectives and methods of approach.

Task IV: Evaluation of Processing Parameters

Objective: Determine which processing parameters are the most critical in modifying sensor response time and threshold level and obtain optimum film processing schedules.

Method of Approach: This effort will consist of:

1. Preparation and evaluation of films made by evaporation in which deposition rate and substrate temperatures are varied over a restricted range.
2. Preparation and evaluation of films made by sputtering in which type, concentration and energy of sputtering ions are varied over a limited range.
3. Evaluation of films that have been annealed at different temperatures in a variety of atmospheres.
4. Evaluation of films that have been bombarded for different times by energetic ions immediately after deposition.
5. Evaluation of overlaid films which have been completely fabricated in vacuum without exposure to air between depositions.

Upon completion of this evaluation, the factors of greatest importance will be investigated to obtain optimization.

In concluding this effort, a number of sensor film samples will be prepared utilizing the optimum overlay materials and techniques developed under this program. These improved films will be extensively evaluated and will be forwarded to NASA for incorporation in the hydrogen detector system. At the present time, delivery of a minimum of film elements is contemplated.

SECTION 6

DELIVERED ITEMS

6.1 GENERAL

The following lists describe those items delivered to the George C. Marshall Space Flight Center/NASA, Huntsville, Alabama, in fulfillment of the requirements of Contract NAS8-5282, "Design, Development and Prototype Fabrication of an Area Hydrogen Detector," by the Research Laboratories Division of the Bendix Corporation.

6.2 REPORTS

Type Reports	RLD Report No.	Date of Issue
Monthly Progress Report 5 April to 1 May 1963	2326	15 May 1963
Monthly Progress Report 1 May to 31 May 1963	2346	15 June 1963
Quarterly Progress Report 5 April to 30 June 1963	2364	15 July 1963
Monthly Progress Report 1 July to 31 July 1963	2385	15 August 1963
Area Hydrogen Detector Breadboard Design	2399	28 August 1963
Monthly Progress Report 1 Ausust to 31 August 1963	2415	12 September 1963
Quarterly Progress Report 1 July to 30 September 1963	2442	15 October 1963
Monthly Progress Report 1 October to 31 October 1963	2473	14 November 1963
Monthly Progress Report 1 November to 30 November 1963	2496	13 December 1963
Quarterly Progress Report 1 October to 31 December 1963	2520	14 January 1964

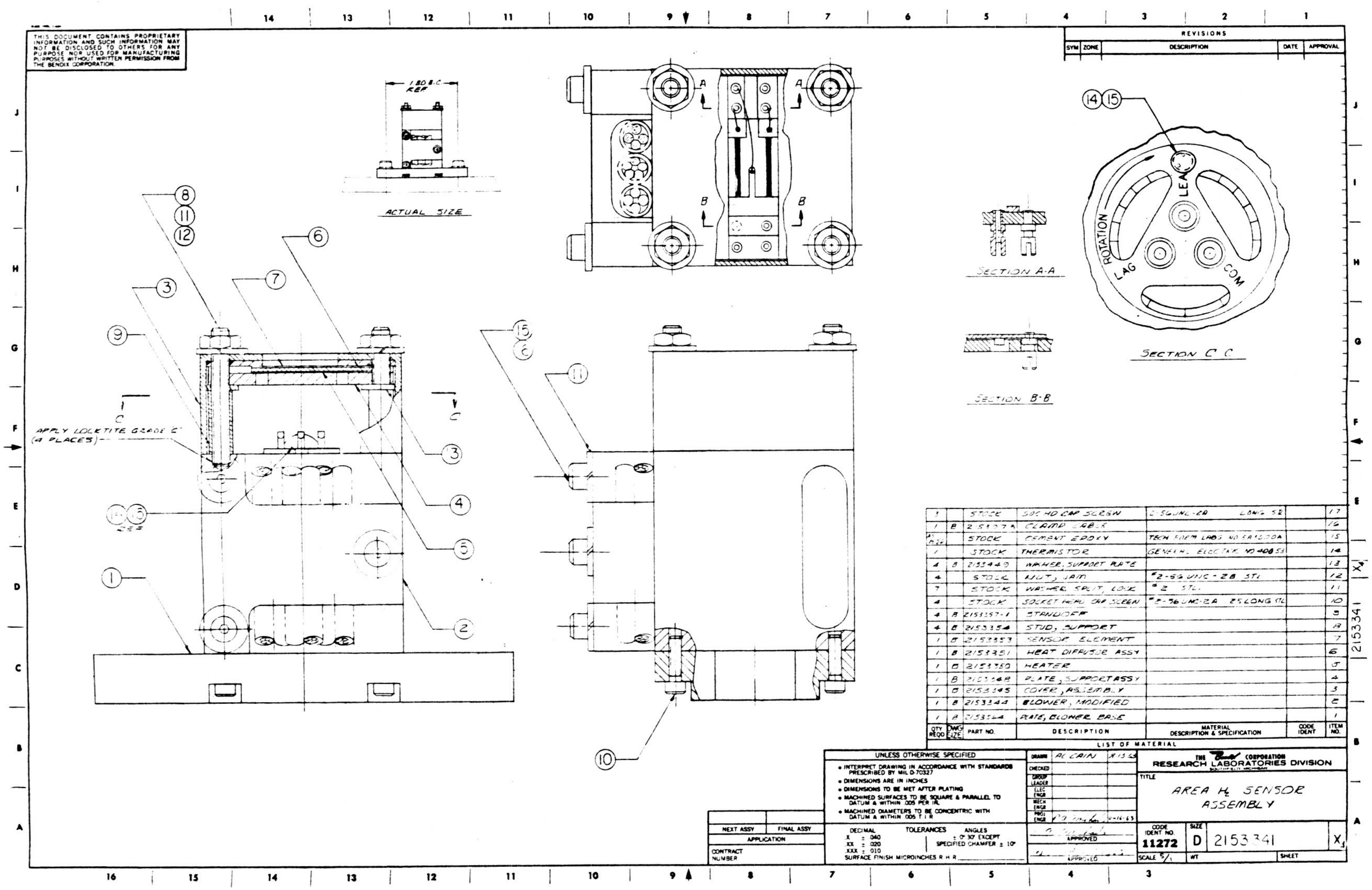
Type Report	RLD Report No.	Date of Issue
Monthly Progress Report 1 January to 31 January	2540	14 February 1964
Monthly Progress Report 1 February to 29 February 1964	2560	16 March 1964
Final Report, 5 April 1963 to 4 April 1964	2573	3 April 1964
Monthly Funding Reports (12)		

6.3 HARDWARE

Item Delivered	Date of Delivery
Area Hydrogen Sensor Assembly (Breadboard) S/N 101 With Sensor Element P102-8 and Filter Pack	16 December 1963
Area Hydrogen Control Assembly (Breadboard) S/N 101	16 December 1963
Power and Control, Cable	16 December 1963
Spare Sensor Element P102-5	16 December 1963
Set Calibration and Wiring Diagram, S/N 101	16 December 1963
Area Hydrogen Sensor Assembly (Prototype) S/N 102 With Sensor Element P102-18 and Filter Pack	13 February 1964
Area Hydrogen Control Assembly (Prototype) S/N 102	13 February 1964
Set Calibration and Wiring Diagram, S/N 102	13 February 1964
Area Hydrogen Sensor Assembly (Prototype) S/N 103 With Sensor Element P102-16 and Filter Pack	13 February 1964
Area Hydrogen Control Assembly (Prototype) S/N 103	13 February 1964
Set Calibration and Wiring Diagram, S/N 103	13 February 1964

6.4 REPRODUCIBLE DOCUMENTATION

Van Dyke copies of all electrical schematics, mechanical engineering drawings, component, and parts lists have been delivered under the Research Laboratories Division documentation number CA-13995. Copies of the reproducible items are presented over leaf.



QTY REQD	DWG SIZE	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
3		STOCK	SOC HD CAP SCREW	2-56UNC-2A LONG ST		17
1	B	2153374	CLAMP CABLE			16
AS REQD		STOCK	CEMENT EPOXY	TECH FORM LABS NO. EA1000A		15
1		STOCK	THERMISTOR	GENERAL ELECTRIC NO 40053		14
4	B	2153449	WASHER, SUPPORT PLATE			13
4		STOCK	NUT, JAM	#2-56 UNC-2B STL		12
7		STOCK	WASHER, SPLIT, LOCK	#2 STL.		11
4		STOCK	SOCKET HEAD CAP SCREW	#2-56 UNC-2A .25 LONG STL		10
4	B	2153357-1	STANDOFF			9
4	B	2153354	STUD, SUPPORT			8
1	B	2153353	SENSOR ELEMENT			7
1	B	2153351	HEAT DIFFUSER ASSY			6
1	B	2153350	HEATER			5
1	B	2153348	PLATE, SUPPORT ASSY			4
1	B	2153345	COVER, ASSEMBLY			3
1	B	2153344	BLOWER, MODIFIED			2
1	B	2153364	PLATE, BLOWER BASE			1

LIST OF MATERIAL

2153564 | X1

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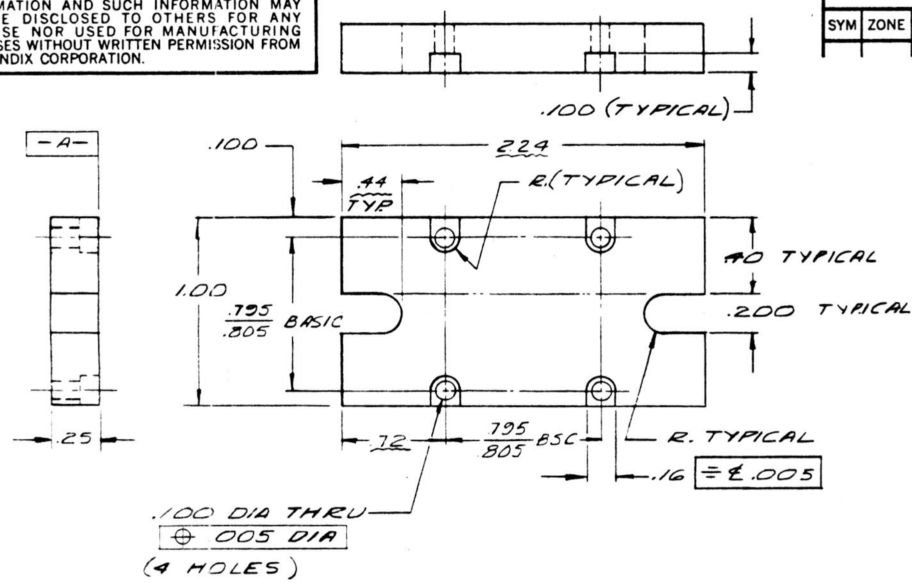
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



			AL. ALLOY 6061 OR 2024		
QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL	ANGLES
.X ± .040	± 0°-30' EXCEPT
.XX ± .020	SPECIFIED CHAMFER ± 10°
.XXX ± .010	

SURFACE FINISH MICROINCHES R H R 63

NEXT ASSY	FINAL ASSY
02153341	
APPLICATION	

CONTRACT NUMBER

DRAWN	AL. CAIN	9-11-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR		
APPROVED		
APPROVED		

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE
PLATE, BLOWER BASE
(AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153564	X1
SCALE 2/1	WT		SHEET

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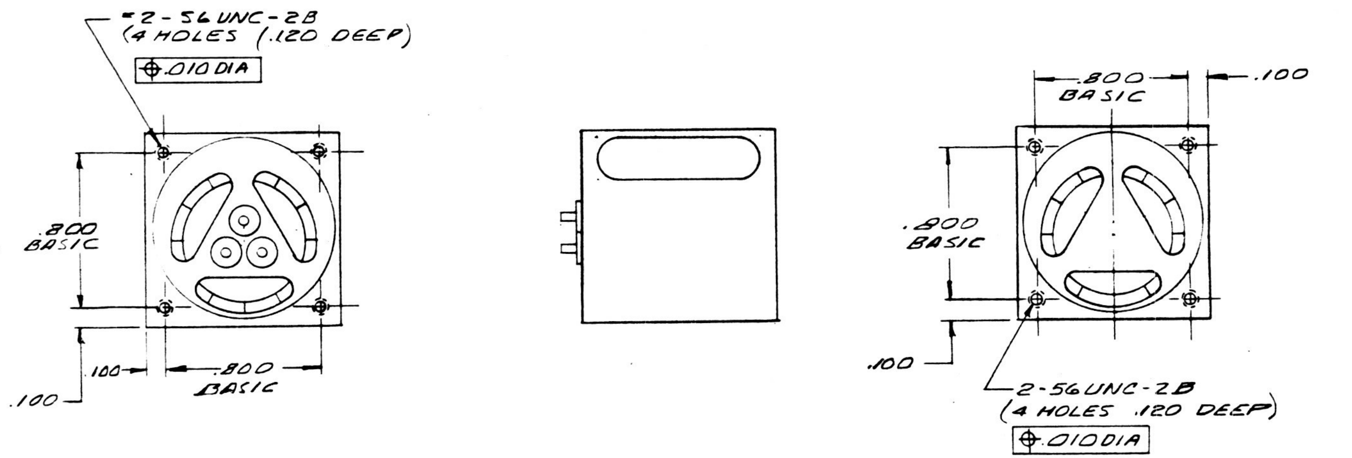
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL

2153344 X2



NOTE.
1. MASK TO PREVENT METAL SHAVINGS FROM FALLING INSIDE OF BLOWER

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
1	STOCK	MINICUBE BLOWER	SANDERS ASSOC. MODEL 2A		

LIST OF MATERIAL

NEXT ASSY	FINAL ASSY
02153341	

APPLICATION

CONTRACT NUMBER 2314-001

UNLESS OTHERWISE SPECIFIED
- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES
DECIMAL: .X ± .040, .XX ± .020, .XXX ± .010
ANGLES: ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°
SURFACE FINISH MICROINCHES R H R ______

DRAWN	AL CAIN	8-14-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	R.C. Michaels	8-26-63

[illegible] 8/26/63
APPROVED

APPROVED

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE
BLOWER MODIFIED
(AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153344	X2
SCALE 2/1	WT		SHEET

2153345 | X2

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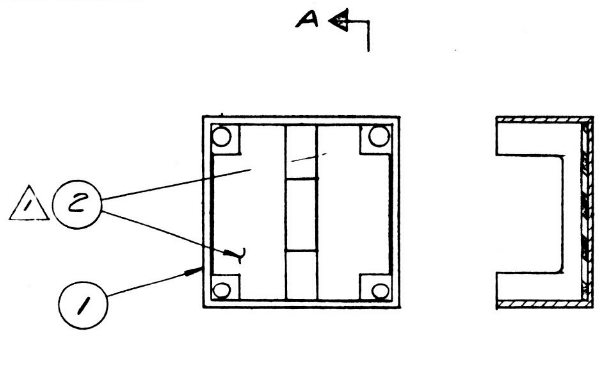
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



SECTION A-A

2153345 | X1

1. USE DOW CORNING ADHESIVE NO. 269

NOTES

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
2	2153347	CUSHION			2
1	2153346	COVER, MODIFIED			1

LIST OF MATERIAL

	D2153341
NEXT ASSY	FINAL ASSY
APPLICATION	
CONTRACT NUMBER Z314-001	

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040; .XX ± .020; .XXX ± .010

ANGLES: ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

DRAWN	AL. CAIN	8-19-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	P A Michals	8-26-63
APPROVED	W D Weller 8/26/63	
APPROVED		

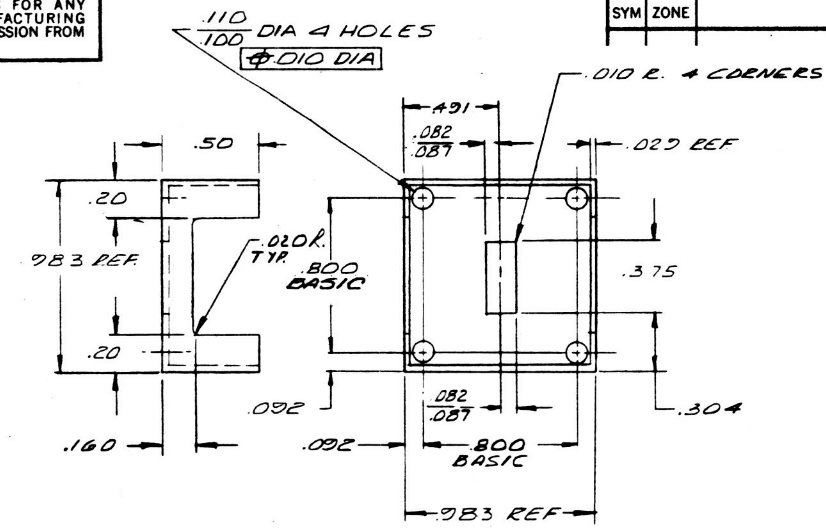
THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE COVER, MODIFIED (SUB-ASSEMBLY) (AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153345	X2
SCALE 2/1	WT	SHEET	

2153346 | X_2

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



SOURCE:
WELLS ELECTRONIC INC.
1701 S. MAIN ST. SO. BEND, INDIANA
PART NO. M5-6-500-D

NOTES

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
1		SHELL	DIALLYL PHTHALATE, ORLON FILLED		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES
DECIMAL: .X ± .040; .XX ± .020; .XXX ± .010
ANGLES: ± 0°30′ EXCEPT SPECIFIED CHAMFER ± 10°
SURFACE FINISH MICROINCHES R H R

NEXT ASSY	FINAL ASSY
B2153345	D2153341
APPLICATION	

CONTRACT NUMBER 2314-001

DRAWN	AL. CAIN	8-19-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	[signature]	8-26-63
APPROVED	[signature]	8/26/63
APPROVED		

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE
COVER, MODIFIED
(AREA H_2 SENSOR)

CODE IDENT NO.	SIZE	DWG NO.	
11272	B	2153346	X_2
SCALE 2/1	WT		SHEET

2153347 X1

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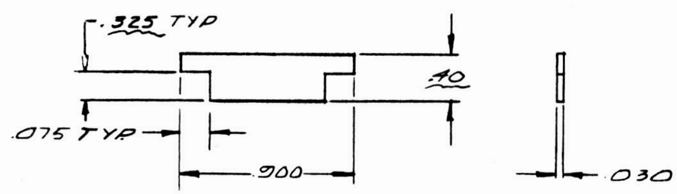
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
2			SILICONE RUBBER		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL
.X ± .040
.XX ± .020
.XXX ± .010

ANGLES
± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

DRAWN	AL CAIN	8-19-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR		

W.W... 8/20/63
APPROVED

APPROVED

NEXT ASSY	FINAL ASSY
BZ153345	DZ153341

APPLICATION

CONTRACT NUMBER 2314-001

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE CUSHION (AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153347	X2
SCALE 2/1	WT		SHEET

2153348 | X_2

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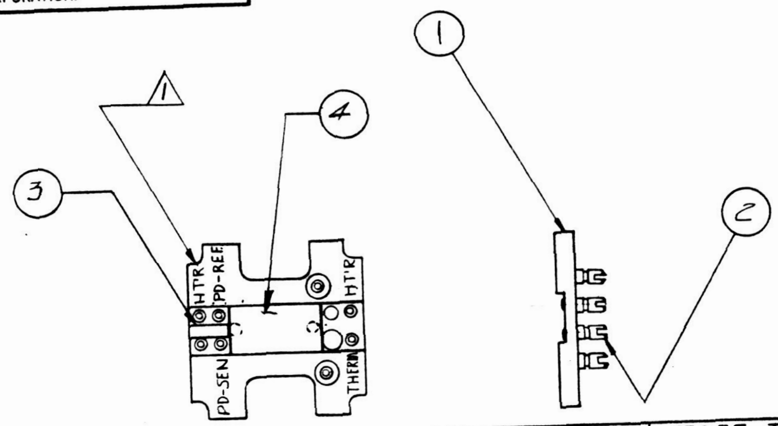
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



SOURCE:
2 THE CONN HARD RUBBER CO.

1 LETTER WITH BLACK INK OR LUSTERLESS BLACK ENAMEL (AIR DRY)

NOTES:

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
1	STOCK	TAPE TEFLON	TEMP-R-TAPE-C .003 THK		4
1	B 2153967	STRIP SPACER			3
8	STOCK	MINIATURE SPLIT TERMINAL	CTC NO. 1089-3		2
1	B 2153349	SUPPORT PLATE			1

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040; .XX ± .020; .XXX ± .010

ANGLES: ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

DRAWN	AL. CAIN 8-22-63
CHECKED	
GROUP LEADER	
ELEC ENGR	
MECH ENGR	
PROJ ENGR	[illegible] 8-26-63
APPROVED	[illegible]
APPROVED	

NEXT ASSY	D2153341
APPLICATION	FINAL ASSY

CONTRACT NUMBER 2314-001

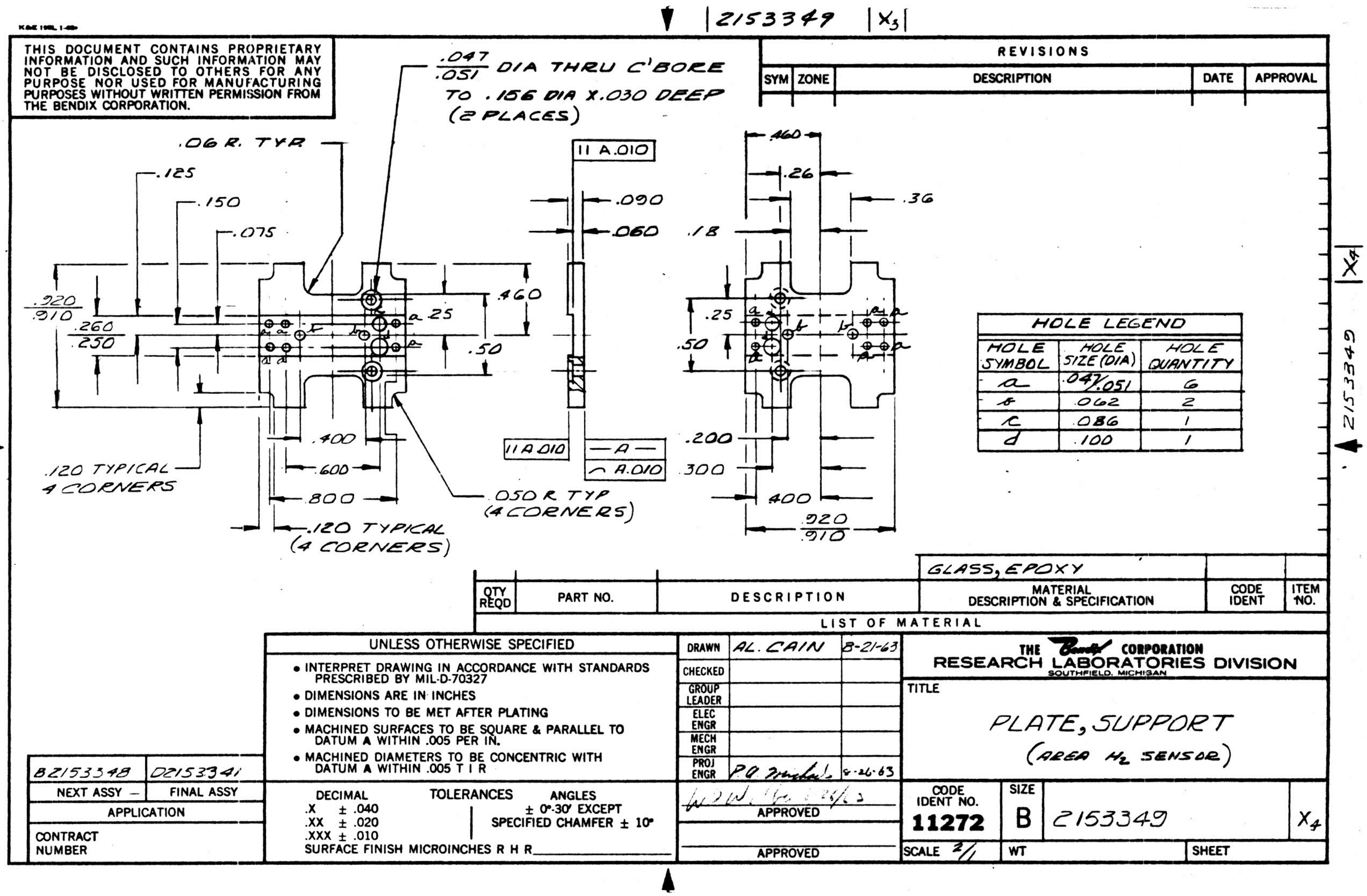
THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE: PLATE, SUPPORT ASSEMBLY (AREA H_2 SENSOR)

CODE IDENT NO. 11272 | SIZE B | 2153348 | X_2

SCALE 2/1 | WT | SHEET

2153348 | X_2


2153349 X3
X4
2153349
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REVISIONS
SYM ZONE DESCRIPTION DATE APPROVAL
.047/.051 DIA THRU C'BORE TO .156 DIA X.030 DEEP (2 PLACES)
.06 R. TYP
.125
.150
.075
.920/.910
.260/.250
.460
.25
.50
.400
.600
.800
.120 TYPICAL 4 CORNERS
.120 TYPICAL (4 CORNERS)
.050 R TYP (4 CORNERS)
A.010
.090
.060
A
.18
.26
.36
.200
.300
HOLE LEGEND
HOLE SYMBOL | HOLE SIZE (DIA) | HOLE QUANTITY
a | .047/.051 | 6
b | .062 | 2
c | .086 | 1
d | .100 | 1
GLASS, EPOXY
QTY REQD | PART NO. | DESCRIPTION | MATERIAL DESCRIPTION & SPECIFICATION | CODE IDENT | ITEM NO.
LIST OF MATERIAL
UNLESS OTHERWISE SPECIFIED
• INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
• DIMENSIONS ARE IN INCHES
• DIMENSIONS TO BE MET AFTER PLATING
• MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
• MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R
TOLERANCES
DECIMAL .X ± .040 .XX ± .020 .XXX ± .010
ANGLES ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°
SURFACE FINISH MICROINCHES R H R
B2153348 | D2153341
NEXT ASSY — | FINAL ASSY
APPLICATION
CONTRACT NUMBER
DRAWN AL. CAIN 8-21-63
CHECKED
GROUP LEADER
ELEC ENGR
MECH ENGR
PROJ ENGR 8-26-63
APPROVED
APPROVED
THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN
TITLE
PLATE, SUPPORT
(AREA H_2 SENSOR)
CODE IDENT NO. 11272
SIZE B
2153349
X4
SCALE 2/1
WT
SHEET

2153967 | X1

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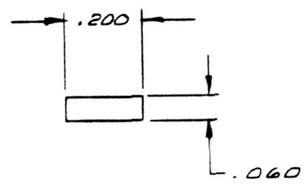
REVISIONS

SYM	ZONE	DESCRIPTION	DATE	APPROVAL



QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
			.020 THK. GLASS EPOXY		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM **A** WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM **A** WITHIN .005 T I R

TOLERANCES

DECIMAL
.X ± .040
.XX ± .020
.XXX ± .010

ANGLES
± 0°-30' EXCEPT
SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R ______

DRAWN	AL. CAIN	11-13-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR		
APPROVED		
APPROVED		

NEXT ASSY	FINAL ASSY
BZ153348	
APPLICATION	
CONTRACT NUMBER	

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE
STRIP, SPACER

CODE IDENT NO.	SIZE		
11272	B	2153967	X1
SCALE 2/1	WT		SHEET

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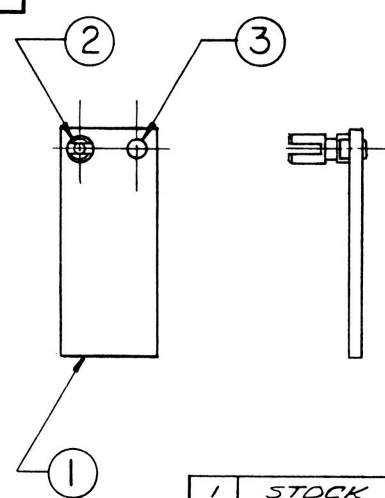
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



2153351 | X1 |

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
1	STOCK	THERMISTOR	G.E. 4DO 51		3
1	STOCK	MINIATURE SPLIT TERMINAL	CTC NO 1089-1		2
1	2153352	HEAT DIFFUSOR			1

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040, .XX ± .020, .XXX ± .010

ANGLES: ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

	D2153341
NEXT ASSY	FINAL ASSY
APPLICATION	
CONTRACT NUMBER	Z3A4-001

DRAWN	AL. CAIN	8-22-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	[illegible]	8-26-63
[illegible] 8/26/63 APPROVED		
APPROVED		

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE

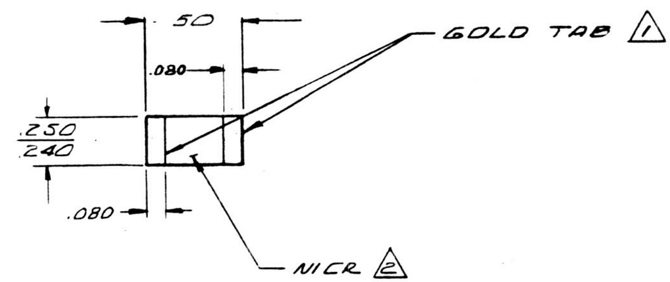
HEAT DIFFUSOR ASSEMBLY

(AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153351	X1
SCALE 4/1	WT		SHEET

2153350 | X2

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



2 SHEET RESISTIVITY SHALL BE 150 OHMS ± 10%

1 SHEET RESISTIVITY SHALL BE LESS THAN 0.5 OHMS PER SQUARE

NOTES

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
		GLASS SUBSTRATE	PYREX GLASS 0.006 THK.		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040; .XX ± .020; .XXX ± .010

ANGLES: ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

DRAWN	AL. CAIN	8-23-62
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	[illegible]	
APPROVED	[illegible]	
APPROVED		

NEXT ASSY	FINAL ASSY
BZ153351	D2153341

APPLICATION

CONTRACT NUMBER 2314-001

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE HEATER (AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153350	X2
SCALE 2/1	WT		SHEET

2153350 | X1

| 2153352 | X4 |

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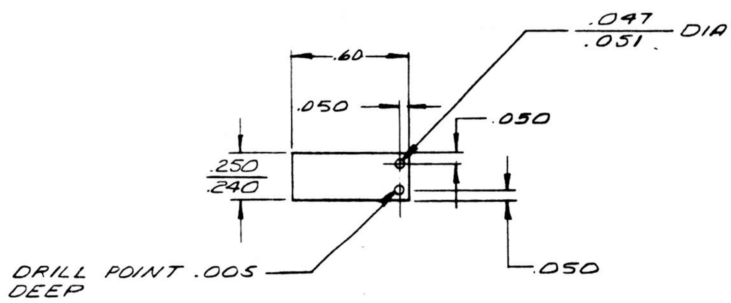
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



FINISH: GOLD PLATE .00005 THICK

NOTES:

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
			PURE SILVER .020 THICK		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040; .XX ± .020; .XXX ± .010

ANGLES: ± 0°-30′ EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

NEXT ASSY	FINAL ASSY
B2153351	D2153341

APPLICATION

CONTRACT NUMBER 2314-001

DRAWN	AL. CAIN	2-23-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	P. U. [illegible]	8-26-63
APPROVED	[illegible]	
APPROVED		

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE: DIFFUSOR, HEAT (AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153352	X4
SCALE	WT	SHEET	

2153352 | X4

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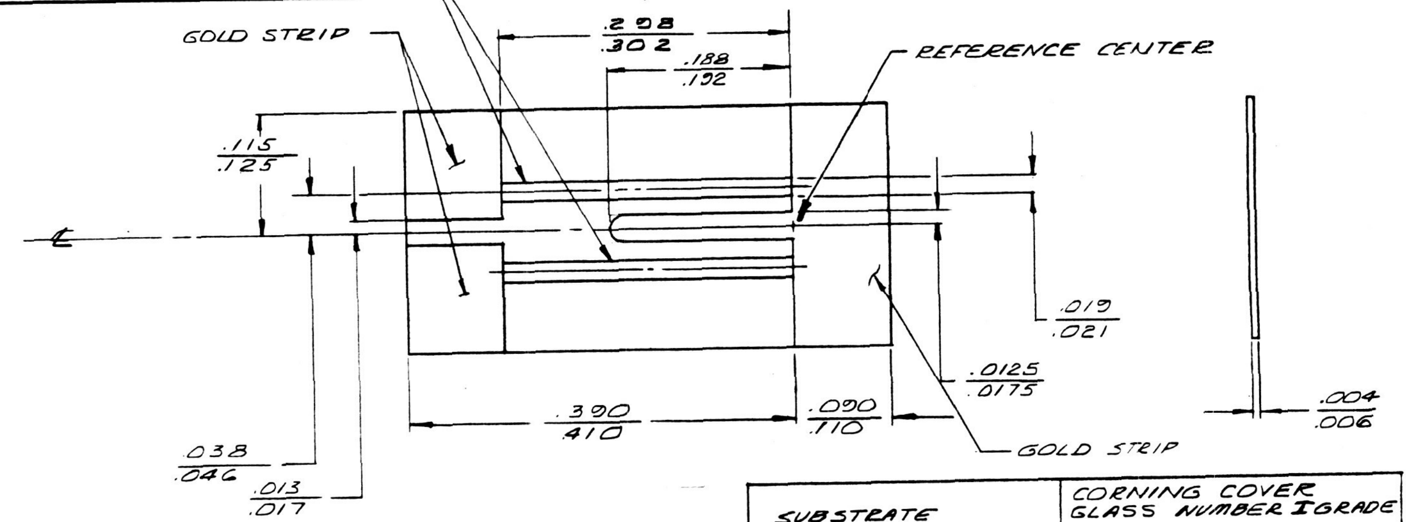
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



ITEM NO.	CODE IDENT	MATERIAL DESCRIPTION & SPECIFICATION	DESCRIPTION	PART NO.	QTY REQD
		CORNING COVER GLASS NUMBER I GRADE	SUBSTRATE		

LIST OF MATERIAL

NOTES:

1. ALL VERTICAL DIMENSIONS ARE SYMMETRICAL ABOUT ℄

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040, .XX ± .020, .XXX ± .010

ANGLES: ± 0°-30′ EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R ______

DRAWN	AL. CAIN	8-20-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	[signature]	8-26-63
APPROVED	[signature] 8/26/63	
APPROVED		

NEXT ASSY	FINAL ASSY
02153341	
APPLICATION	

CONTRACT NUMBER 2314-001

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE: HYDROGEN SENSOR ELEMENT (AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153353	X,
SCALE 10/1	WT	SHEET	

2153353 | X, |

2153354 X1

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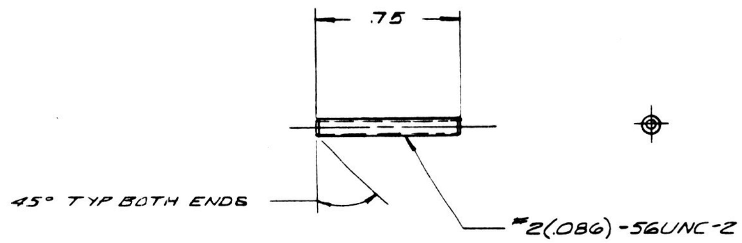
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
		SCREW	ST STL. #2-56UNC-2 1" LONG		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES
DECIMAL: .X ± .040; .XX ± .020; .XXX ± .010
ANGLES: ± 0°30' EXCEPT SPECIFIED CHAMFER ± 10°
SURFACE FINISH MICROINCHES R H R

DRAWN	AL. CAIN	8-22-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	[signature]	8-26-63
APPROVED	[signature]	
APPROVED		

NEXT ASSY	FINAL ASSY
	D2153341

APPLICATION

CONTRACT NUMBER 2314-001

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE: STUD, SUPPORT
AREA H_2 SENSOR

CODE IDENT NO.	SIZE		
11272	B	2153354	X1
SCALE 2/1	WT	SHEET	

2153354 X1

2153357 | X4

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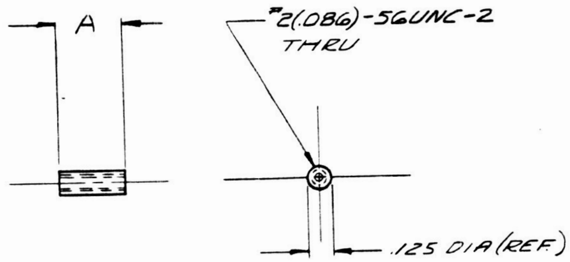
REVISIONS

SYM	ZONE	DESCRIPTION	DATE	APPROVAL



X5 | 2153357

QTY REQD	PART NO.	A	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
	2153357-2	.470/.480		.125 O.D X .069 I.D STAINLESS STEEL TUBING		
	2153357-1	.335/.325		.125 O.D. X .069 I.D. STAINLESS STEEL TUBING		

LIST OF MATERIAL

NOTES.

1. REMOVE ALL BURRS AND BREAK ALL SHARP EDGES .005

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL	ANGLES
.X ± .040 .XX ± .020 .XXX ± .010	± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

NEXT ASSY	FINAL ASSY
	D2153341

APPLICATION

CONTRACT NUMBER 2314-001

DRAWN	AL. CAIN	8-22-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	[illegible]	8-26-63

[illegible]
APPROVED

APPROVED

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE

STANDOFF

(AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153357 (CHARTED)	X4
SCALE 2/1	WT		SHEET

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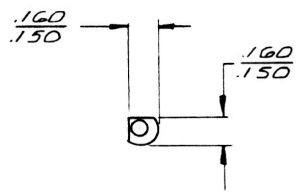
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



NOTES:

1. REMOVE ALL BURRS AND BREAK ALL SHARP EDGES

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
		WASHER NO. 2	BRASS .18 O.D. X.09 I.D X.023 THICK		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL
.X ± .040
.XX ± .020
.XXX ± .010

ANGLES
± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

DRAWN	AL CAIN	8-22-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR	P. A. Michels	8-26-63
APPROVED	[illegible]	8/26/63
APPROVED		

NEXT ASSY	FINAL ASSY D2153341
APPLICATION	

CONTRACT NUMBER 2314-001

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE
WASHER, SUPPORT PLATE
AREA H_2 SENSOR

CODE IDENT NO.	SIZE		
11272	B	2153449	X1
SCALE 2/1	WT		SHEET

2153449 X1

2153973 X2

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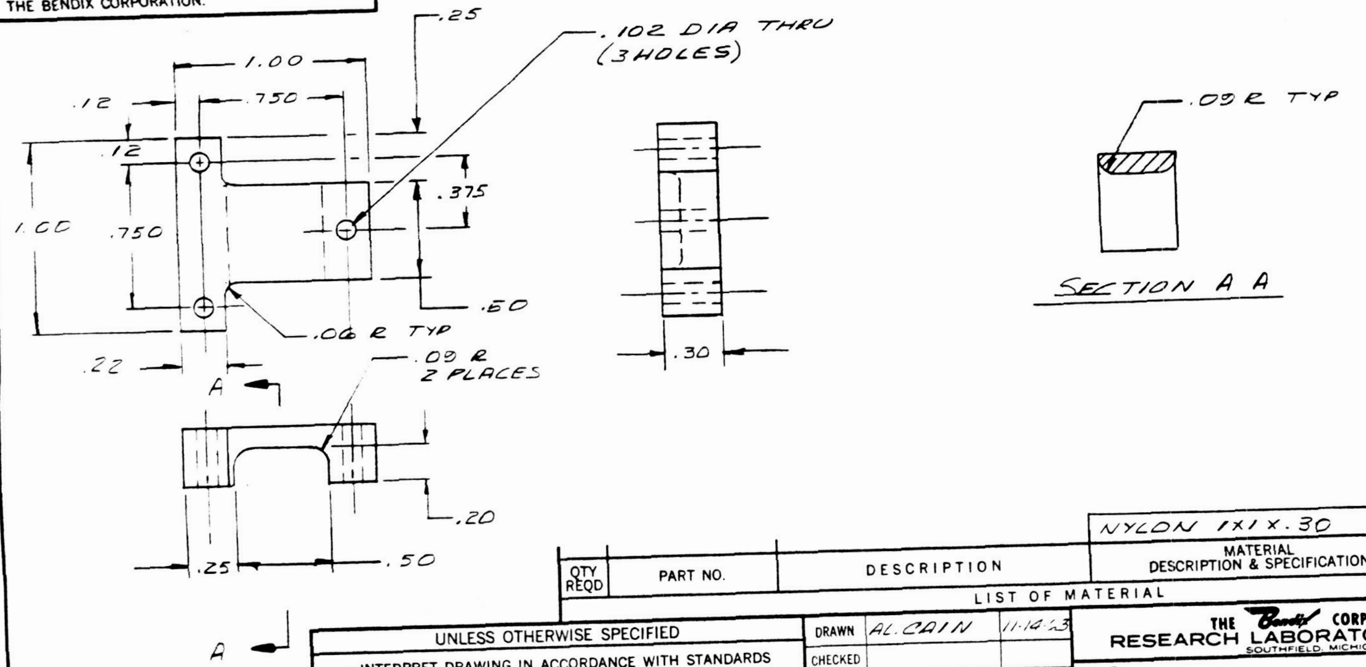
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



ITEM NO.	CODE IDENT	MATERIAL DESCRIPTION & SPECIFICATION	DESCRIPTION	PART NO.	QTY REQD
		NYLON 1X1X.30			

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
- DIMENSIONS ARE IN INCHES
- DIMENSIONS TO BE MET AFTER PLATING
- MACHINED SURFACES TO BE SQUARE & PARALLEL TO DATUM A WITHIN .005 PER IN.
- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040; .XX ± .020; .XXX ± .010

ANGLES: ± 0°30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

NEXT ASSY	FINAL ASSY
C2153341	
APPLICATION	

CONTRACT NUMBER

DRAWN	AL. CAIN	11-14-73
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR		
APPROVED		
APPROVED		

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE: CLAMP, CABLE (AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153973	X2
SCALE 2/1	WT		SHEET

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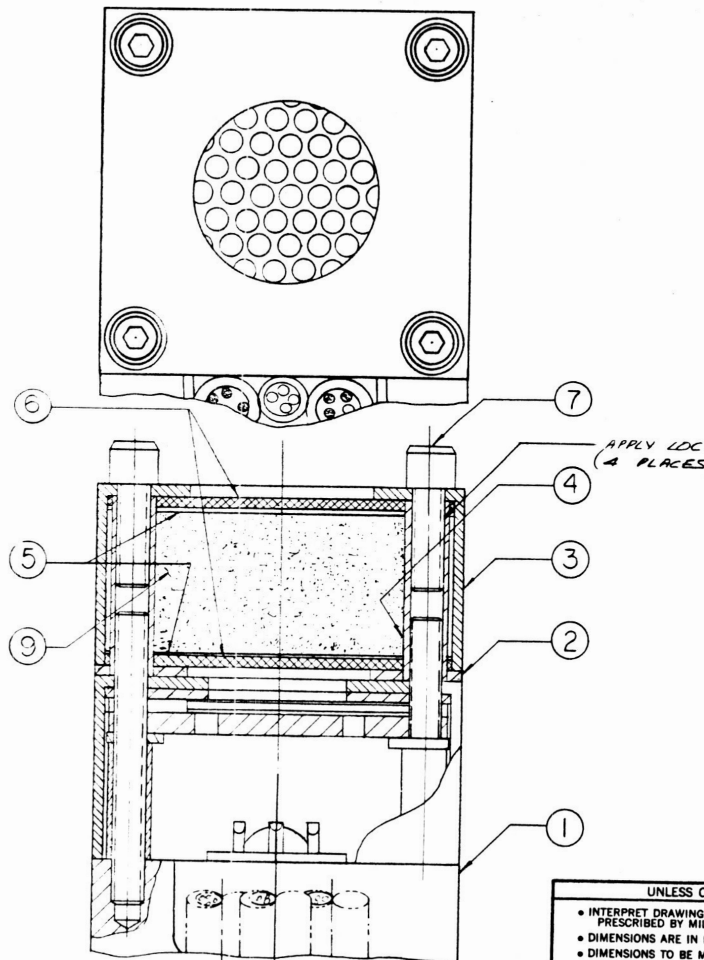
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



QTY REQD	DWG SIZE	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
AS REQ'D		STOCK	CHARCOAL GRANULAR	G-14 MESH BY MATHESON COLMAN AND BELL		9
4		STOCK	SCREW SOC. HD CAP	#2-56UNC-2A X .31 LG.		7
2	B	2153675	FILTER, METAL			6
2		STOCK	FILTER, CLOTH	NO. 123 BY CARL SCHLEICHER AND SCHUELL CO.		5
4	B	2153357-2	STANDOFF			4
1	B	2153674	COVER, FILTER			3
1	B	2153677	GASKET .032 THK.	RUBBER SILICONE		2
1	D	2153341	AREA H_2 SENSOR			1

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

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- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040, .XX ± .020, .XXX ± .010

ANGLES: ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

NEXT ASSY	FINAL ASSY
APPLICATION	
CONTRACT NUMBER	

DRAWN	AL. CAIN	9-30-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR		
APPROVED		
APPROVED		

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE

AREA H_2 SENSOR FILTER ASSEMBLY

CODE IDENT NO.	SIZE		
11272	C	2153676	X4
SCALE 5X	WT		SHEET

2153674 X,

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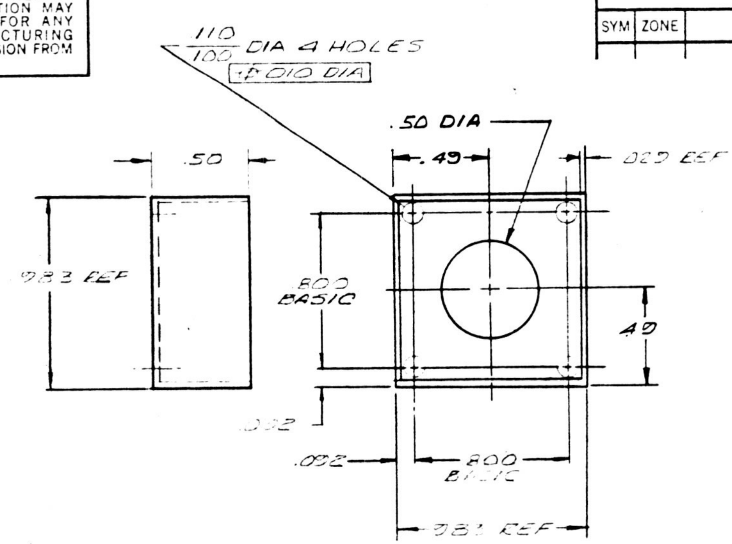
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



SOURCE:
WELLS ELECTRONIC INC.
1701 S. MAIN ST. SO. BEND, INDIANA
PART NO. MS-6-500-D

NOTES

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
1		SHELL			

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED
- INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
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- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES
DECIMAL .X ± .040 .XX ± .020 .XXX ± .010
ANGLES ± 0°30' EXCEPT SPECIFIED CHAMFER ± 10°
SURFACE FINISH MICROINCHES R H R

DRAWN MCLAIN 10-1-63
CHECKED
GROUP LEADER
ELEC ENGR
MECH ENGR
PROJ ENGR
APPROVED
APPROVED

D2153676	2153676
NEXT ASSY	FINAL ASSY
APPLICATION	

CONTRACT NUMBER 2314-001

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION

TITLE
COVER, FILTER
(AREA H_2 SENSOR)

CODE IDENT NO. 11272 SIZE B 2153674 X,
SCALE 2/1 WT SHEET

K&E 199L 1-62

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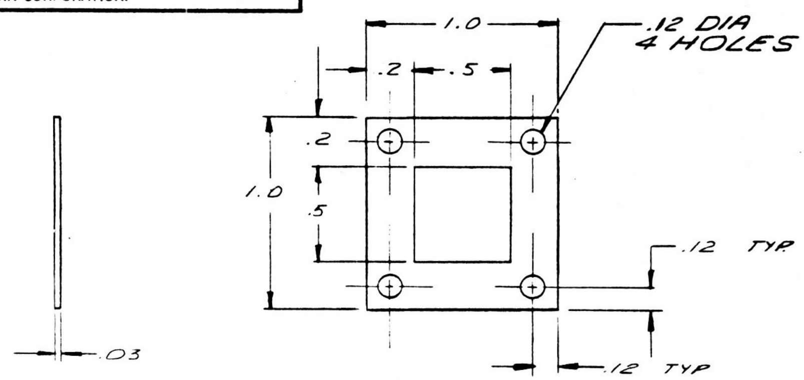
2153677 | X2

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
			.03 THK SILICONE RUBBER		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

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- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL
.X ± .040
.XX ± .020
.XXX ± .010

ANGLES
± 0°-30' EXCEPT
SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

NEXT ASSY	FINAL ASSY
2153676	
APPLICATION	
CONTRACT NUMBER	

DRAWN	AL CAIN	10.1.63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR		
APPROVED		
APPROVED		

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE

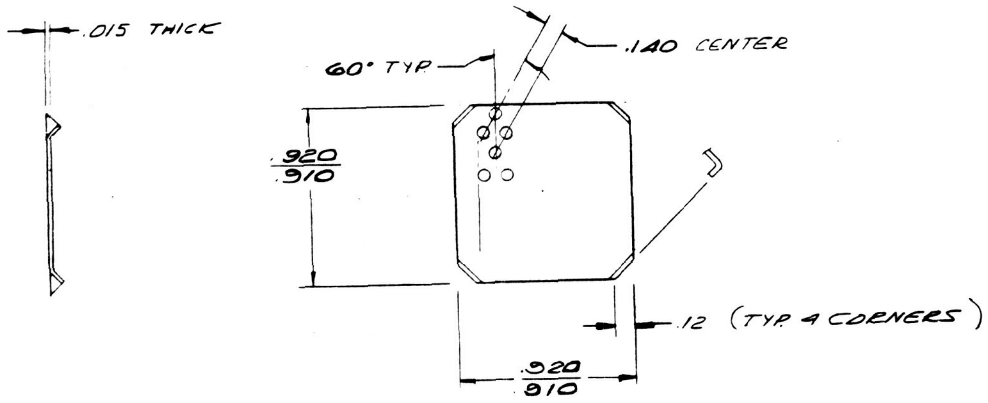
GASKET
AREA H_2 SENSOR

CODE IDENT NO.	SIZE		
11272	B	2153677	X2
SCALE 2/1	WT		SHEET

2153677 | X2

2153675 | X3

REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



2153675 | X1

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
1	STOCK	38 HOLES PER SQ IN	.015 THK ST.STL SHT .062 DIA PERFORATED ON .140 STAGGARD CENTERS		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

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- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL	ANGLES
.X ± .040	± 0°-30' EXCEPT
.XX ± .020	SPECIFIED CHAMFER ± 10°
.XXX ± .010	

SURFACE FINISH MICROINCHES R H R

NEXT ASSY	FINAL ASSY
D2153676	D2153676
APPLICATION	
CONTRACT NUMBER	

DRAWN	AL CAIN	9-30-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR		
APPROVED		
APPROVED		

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE
FILTER, METAL
(AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	B	2153675	X3
SCALE 2/1	WT		SHEET

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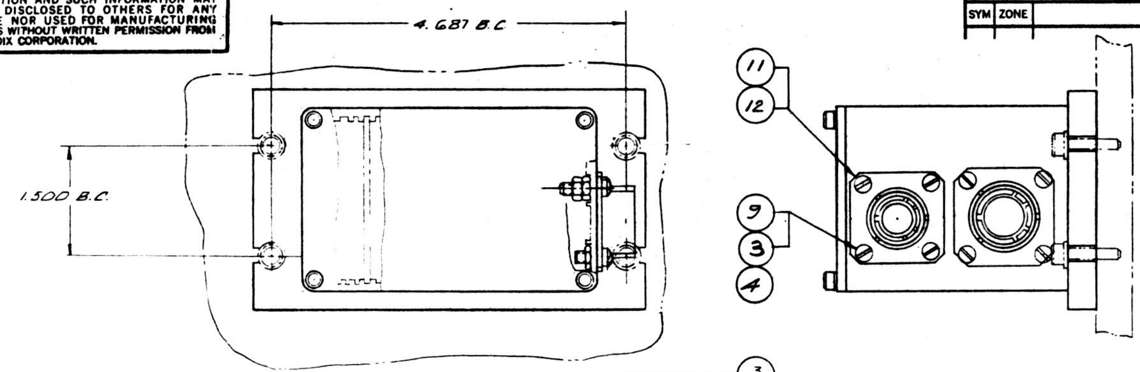
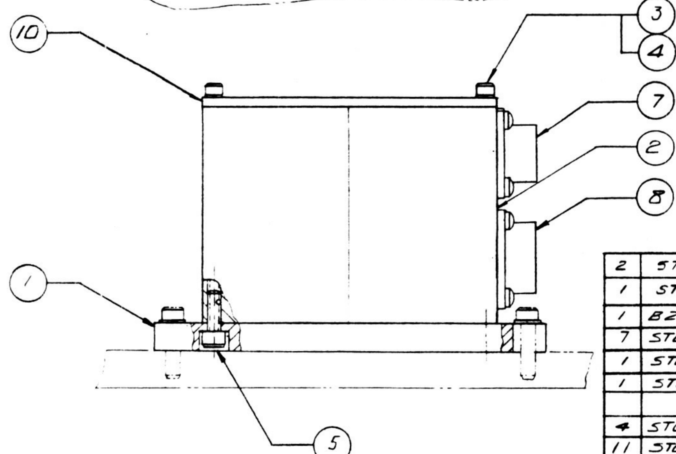
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL





QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
2	STOCK	NUT #6-32	NYLON		12
1	STOCK	SCREW #6-32 X .50 LG.	NYLON		11
1	B2153563	COVER			10
7	STOCK	NUT, JAM	NO. 6-32UNC-2B ST. STL.		9
1	STOCK	RECEPTACLE BOX MTG.	BENDIX PART NO. SP02E-14-15S		8
1	STOCK	RECEPTACLE BOX MTG	BENDIX PART NO. SP02E-12-10P		7
4	STOCK	SCREW SOC. HD CAP (NYLOK)	#8-32 X .38 LG S.S.T.		5
11	STOCK	WASHER, LOCK, SPLIT	#6 MEDIUM ST. STL.		4
11	STOCK	SCREW SOC HD CAP ST. STL	#6-32UNC-2A X .38 LONG		3
1	C2153562	CHASSIS ASSEMBLY			2
1	C2153561	PLATE MOUNTING			1

LIST OF MATERIAL

NEXT ASSY	FINAL ASSY
APPLICATION	
CONTRACT NUMBER	

UNLESS OTHERWISE SPECIFIED

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- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL: .X ± .040; .XX ± .020; .XXX ± .010

ANGLES: ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°

SURFACE FINISH MICROINCHES R H R

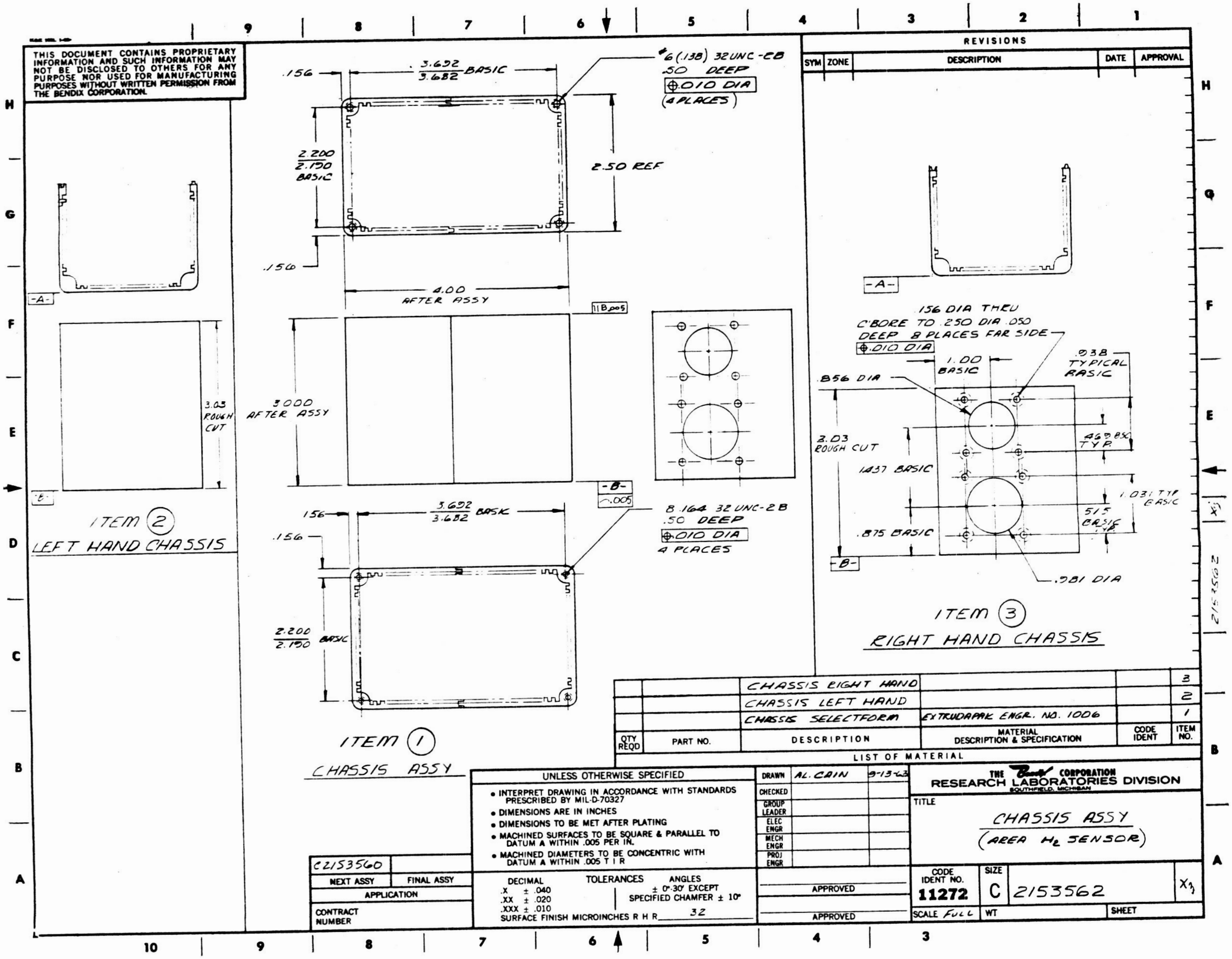
DRAWN	AL. CAIN	9-11-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR		
APPROVED		
APPROVED		

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE

CONTROL ASSEMBLY
(AREA H_2 SENSOR)

CODE IDENT NO.	SIZE		
11272	C	2153560	X_9
SCALE FULL	WT		SHEET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REVISIONS
SYM ZONE DESCRIPTION DATE APPROVAL
ITEM 2 LEFT HAND CHASSIS
3.03 ROUGH CUT
ITEM 1 CHASSIS ASSY
.156
3.692 / 3.682 BASIC
2.200 / 2.190 BASIC
2.50 REF
#6 (.138) 32UNC-2B .50 DEEP ⌖.010 DIA (4 PLACES)
4.00 AFTER ASSY
3.000 AFTER ASSY
8 .164 32 UNC-2B .50 DEEP ⌖.010 DIA 4 PLACES
ITEM 3 RIGHT HAND CHASSIS
.156 DIA THRU C'BORE TO .250 DIA .050 DEEP 8 PLACES FAR SIDE ⌖.010 DIA
1.00 BASIC
.938 TYPICAL BASIC
.856 DIA
3.03 ROUGH CUT
1.437 BASIC
.469 BSC TYP
1.031 TYP BASIC
.515 BASIC TYP
.875 BASIC
.981 DIA
-A-
-B-
LIST OF MATERIAL
QTY REQD | PART NO. | DESCRIPTION | MATERIAL DESCRIPTION & SPECIFICATION | CODE IDENT | ITEM NO.
CHASSIS RIGHT HAND | 3
CHASSIS LEFT HAND | 2
CHASSIS SELECTFORM | EXTRUDAPAK ENGR. NO. 1006 | 1
UNLESS OTHERWISE SPECIFIED
• INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
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• MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R
TOLERANCES
DECIMAL .X ± .040 .XX ± .020 .XXX ± .010
ANGLES ± 0°-30' EXCEPT SPECIFIED CHAMFER ± 10°
SURFACE FINISH MICROINCHES R H R 32
C2153560 NEXT ASSY FINAL ASSY APPLICATION
CONTRACT NUMBER
DRAWN AL. CAIN 9-13-63
CHECKED
GROUP LEADER
ELEC ENGR
MECH ENGR
PROJ ENGR
APPROVED
APPROVED
THE Bendix CORPORATION RESEARCH LABORATORIES DIVISION SOUTHFIELD, MICHIGAN
TITLE CHASSIS ASSY (AREA H2 SENSOR)
CODE IDENT NO. 11272
SIZE C
2153562
SCALE FULL
WT
SHEET

2153563 X2

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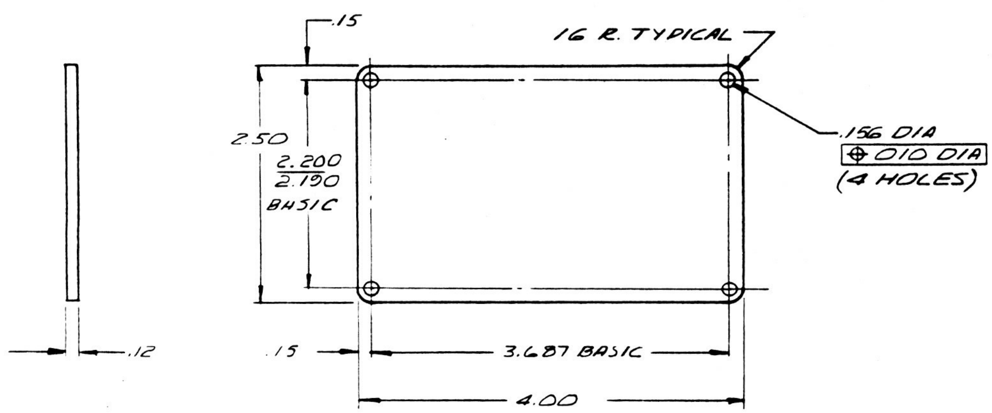
REVISIONS				
SYM	ZONE	DESCRIPTION	DATE	APPROVAL



2153563 X1

QTY REQD	PART NO.	DESCRIPTION	MATERIAL DESCRIPTION & SPECIFICATION	CODE IDENT	ITEM NO.
			AL ALLOY 5052 H32		

LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED

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- MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R

TOLERANCES

DECIMAL	ANGLES
.X ± .040	± 0°-30' EXCEPT
.XX ± .020	SPECIFIED CHAMFER ± 10°
.XXX ± .010	

SURFACE FINISH MICROINCHES R H R 63

NEXT ASSY	FINAL ASSY

APPLICATION

CONTRACT NUMBER

DRAWN	AL. CAIN	9-11-63
CHECKED		
GROUP LEADER		
ELEC ENGR		
MECH ENGR		
PROJ ENGR		

APPROVED

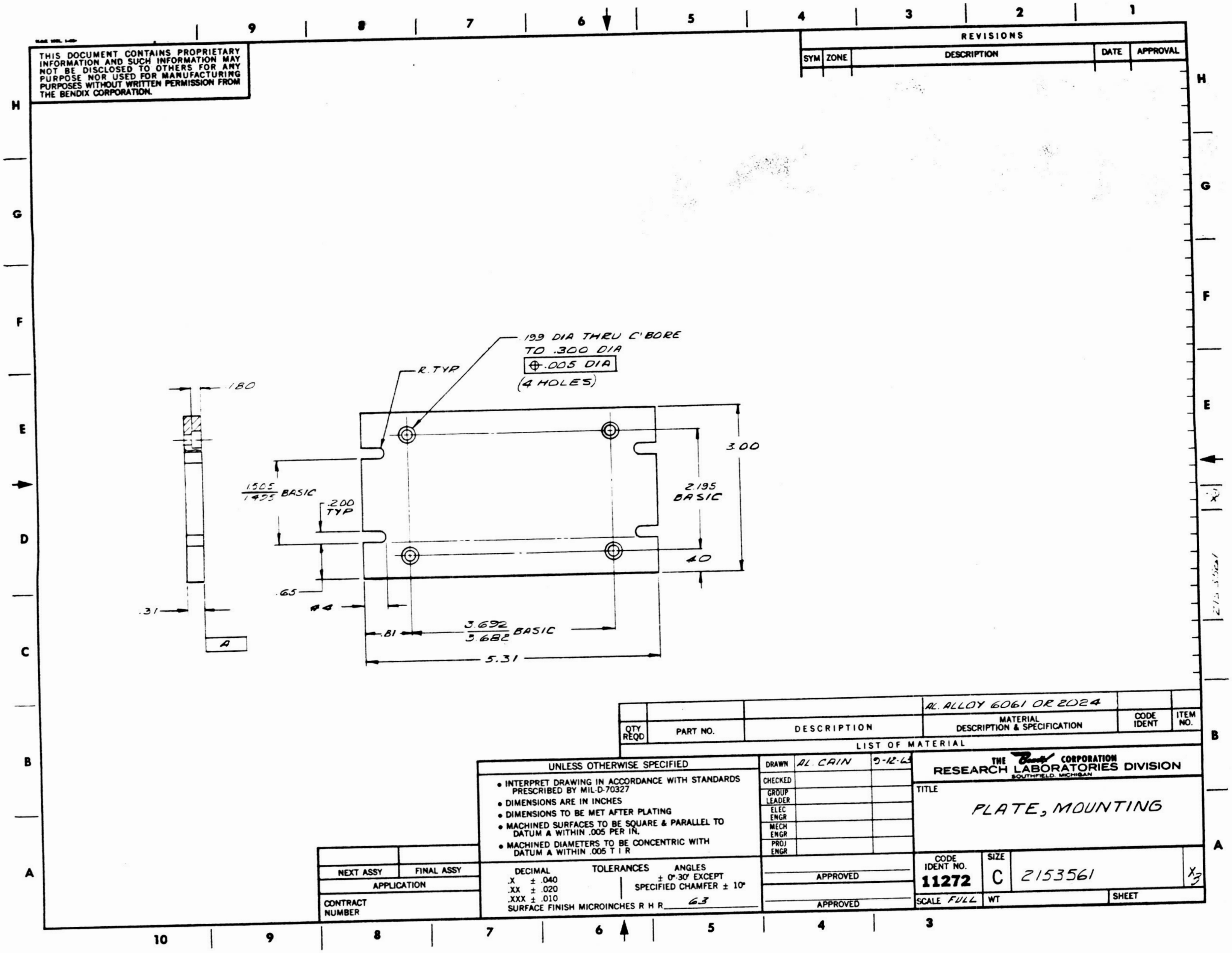
APPROVED

THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN

TITLE

COVER

CODE IDENT NO.	SIZE		
11272	B	2153563	X2
SCALE FULL	WT		SHEET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REVISIONS
SYM
ZONE
DESCRIPTION
DATE
APPROVAL
.199 DIA THRU C'BORE TO .300 DIA
⊕ .005 DIA
(4 HOLES)
R. TYP
.180
.31
A
1.505 / 1.495 BASIC
.200 TYP
.65
3.00
2.195 BASIC
.40
.81
3.692 / 3.682 BASIC
5.31
AL. ALLOY 6061 OR 2024
QTY REQD
PART NO.
DESCRIPTION
MATERIAL DESCRIPTION & SPECIFICATION
CODE IDENT
ITEM NO.
LIST OF MATERIAL
UNLESS OTHERWISE SPECIFIED
• INTERPRET DRAWING IN ACCORDANCE WITH STANDARDS PRESCRIBED BY MIL-D-70327
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• MACHINED DIAMETERS TO BE CONCENTRIC WITH DATUM A WITHIN .005 T I R
TOLERANCES
DECIMAL
.X ± .040
.XX ± .020
.XXX ± .010
ANGLES
± 0°-30' EXCEPT
SPECIFIED CHAMFER ± 10°
SURFACE FINISH MICROINCHES R H R 63
NEXT ASSY
FINAL ASSY
APPLICATION
CONTRACT NUMBER
DRAWN AL. CAIN 9-12-63
CHECKED
GROUP LEADER
ELEC ENGR
MECH ENGR
PROJ ENGR
APPROVED
APPROVED
THE Bendix CORPORATION
RESEARCH LABORATORIES DIVISION
SOUTHFIELD, MICHIGAN
TITLE
PLATE, MOUNTING
CODE IDENT NO.
11272
SIZE
C
2153561
SCALE FULL
WT
SHEET